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ABSTRACT

This document augments and extends the 1978 "Science Framework for California Public Schools, Kindergarten and Grades One Through Twelve." It is designed to be used with the Framework in: (1) developing articulated kindergarten through twelfth grade science programs based on information in the Framework; (2) stimulating science teaching and learning at all levels, but especially in the elementary schools; (3) developing state and local assessment instruments in science; (4) integrating science with other curriculum areas; and (5) developing and selecting better textbooks and other instructional materials to support the teaching of science. It includes: a model of expectations for learners' achievement in science (addressing the knowledge, concepts, technological applications, ethical concerns, and processes students should learn in grades K-3, 3-6, 6-9, and 9-12); uses of the model (by grade level spans) for specific subject areas within the biological, physical, and earth sciences; discussions of ethical issues and electronic technology in the science classroom; suggestions for staff development programs to enhance science instruction; criteria for evaluating instructional materials; statement of the California State Board of Education's antidogmatism policy; and Education Code sections of special relevance to science educators. (JN)

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SCIENCE
Framework Addendum
for California Public Schools

Kindergarten and Grades One Through Twelve

Prepared by the
Science Curriculum Framework and Criteria Committee

Under the direction of the
California State Board of Education
Curriculum Development and Supplemental Materials Commission

And adopted by the
California State Board of Education

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Contents

	Page
Foreword	iv
Preface	vi
Acknowledgments	vii
Expectations for Learners' Achievement in Science—A Model	1
Science, Technology, Individuals, and Society	8
Biological Science—Cells, Genetics, and Evolution	14
Biological Science—Plants	21
Biological Science—Protists	26
Biological Science—Animals	28
Biological Science—Human Beings	32
Biological Science—Ecosystems	38
Earth Science—Astronomy	43
Earth Science—Geology and Natural Resources	47
Earth Science—Meteorology	53
Earth Science—Oceanography	57
Physical Science—Matter	60
Physical Science—Mechanics	69
Physical Science—Energy: Sources and Transformations	72
Physical Science—Energy: Heat	75
Physical Science—Energy: Light	78
Physical Science—Energy: Electricity and Magnetism	83
Physical Science—Energy: Sound	87
Ethical Issues in the Science Classroom	91
Staff Development for Better Science Teaching	92
Electronic Technology in the Science Classroom	98
Criteria for Evaluating Instructional Materials in Science (1984 Revision)	103
State Board of Education's Antidogmatism Policy	106
***Education Code* Sections of Special Relevance to Science Educators**	107

Foreword

When John Dewey stated that science "should take its rightful place in the center of the curriculum," he spoke for his time and for our future. It is time to examine Dewey's proclamation and work to revitalize science teaching in our schools in a way that is reminiscent of the post-Sputnik era, but with a clearer vision and grander goals.

Our goal for science education—and all educators and concerned citizens should share this goal—is to bring about the scientific literacy of all California students. The term *scientific literacy* has a number of meanings, but it is generally acknowledged to include developing an active interest in how scientific and technological advances influence our daily lives, learning the fundamental concepts of science that enable learners to understand natural phenomena and occurrences of human origin, and applying these attitudes and conceptual understandings to live as informed citizens in the technologically preeminent society in the world. The companion goal of encouraging and challenging our greatest natural resource—our children—is mutually supportive of the goal to achieve scientific literacy. Teaching more science in the elementary grades reinforces both goals.

Creating an academic environment that recognizes the importance of science to lives outside school also supports scientific literacy for all and rigorous preparation in science for the few—but growing numbers of—students selecting science, medicine, and engineering fields. The need for maintaining and expanding our higher level coursework in science is evident. California has roughly 10 percent of the nation's population; yet, our state employs about 20 percent of the people in the nation's highly specialized scientific and technological occupations. Our state and national well-being depends, in large part, on the products of California's public schools.

John Dewey's remark about the centrality of science education fits in with our larger ambitions for students in California. The need to integrate various segments of the curriculum is obvious. Science is a perfect vehicle for improving students' reading, writing, and computation skills. It has high student interest and a host of applications. Science also furthers the need to sharpen students' critical thinking skills through scientific knowing and inquiry. It helps develop moral fiber through discussions of ethical issues based on thorough understanding of scientific concepts. Finally, the study of science helps to preserve our democratic institutions through the economic gains derived from scientific and technological superiority and through the brave decisions made by a scientifically informed citizenry.

Science is basic. It is a course of study that students should experience continuously throughout their time in school. The *Science Framework Addendum* endorses science for all learners in the expectation that all students should be exposed to and gain from this instruction. Science can and should be taught as an integral part of the federal and state categorical programs, so that students with special needs receive a quality science education program. Science concepts are universal; therefore, bilingual programs can take advantage of this international language, allowing students to participate in science experiments and to develop oral language skills by explaining the event to others. As mentioned above, science as a priority curricular area can prepare the most able students for postsecondary studies and the world of work.

The *Science Framework Addendum* augments the original 1978 *Science Framework* with specificity and certitude that set a standard for the forthcoming textbook adoption in science and in the frameworks for other curriculum areas. The *Addendum* articulates what students should learn by specifying the concepts to be learned at various grade-level spans and, with

intentional overlap between adjacent spans, shows the spiraling development of conceptual understanding.

While the *Addendum* is quite specific, it is not overly prescriptive; considerable flexibility is allowed for local autonomy and unique student needs. The *Addendum* represents the best attempt of California's science educators to delineate what students should learn. Please read and use this publication thoroughly so that science can once again be at the center of the curriculum.

Bill Honig

Superintendent of Public Instruction

Preface

The *Science Framework Addendum for California Public Schools* was developed by science educators throughout California to present a model of expectations in scientific literacy for students in kindergarten through the twelfth grade. These educators determined that an addendum was more appropriate than a complete revision of the 1978 *Science Framework*. This *Addendum*, therefore, is an extension of the 1978 *Science Framework for California Public Schools* and is intended to be used in conjunction with the framework.

This *Addendum* is the State Board of Education's means of informing educators in the state of its recommendations concerning the science curriculum. These recommendations have as their base the California State Board of Education's *Raising Expectations: Model Graduation Requirements;* the State Department of Education's "Model Curriculum Standards," which were in draft form when we went to press with the *Addendum;* and the National Commission on Excellence in Education's *A Nation at Risk*. Supporting the State Board of Education's position was the Curriculum Development and Supplemental Materials Commission, which was directly involved in providing guidance to the Science Curriculum Framework and Criteria Committee. Staff from various offices and units throughout the Department of Education made major contributions to the development of the *Addendum*.

The Science Curriculum Framework and Criteria Committee was well aware of the rapidly occurring advancements in scientific knowledge and of our instructional system's limitations in assimilating and converting this information into meaningful applications—formal, ethical, political, or technical. To improve instruction in science, the committee members developed a broad-based science questionnaire that was distributed statewide, and they reviewed science papers and journals related to education. These numerous attempts to identify the level, intent, and direction of science education in California's public schools are the foundation on which the *Science Framework Addendum* is based.

We encourage all of you who use the *Addendum* to let us know of its specific value and use. Please direct your responses to the Science Education Unit, California State Department of Education, 721 Capitol Mall, Sacramento, CA 95814-4785.

The State Board of Education, the Curriculum Commission, and we in the Department of Education are most grateful for the contributions provided and the commitment shown by the Science Curriculum Framework and Criteria Committee in its quest to upgrade science education in California's public schools.

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Expectations for Learners' Achievement in Science—A Model

The need for a model of expectations for learners' achievement in science has been expressed with increasing frequency and forcefulness by California science education leaders during recent years. It is hoped that this extension of the 1978 *Science Framework for California Public Schools, Kindergarten and Grades One Through Twelve,* will be useful in:

1. Developing articulated kindergarten through twelfth grade science programs based on the *Science Framework*
2. Stimulating science teaching and learning at all levels, but especially in the elementary schools
3. Developing state and local assessment instruments (e.g., California Assessment Program tests) in science
4. Integrating science with other curriculum areas
5. Developing and selecting better textbooks and other instructional materials to support the teaching of science

It is hoped that a statement of what we might expect *all* learners to understand and be able to do in science will help to establish (or reestablish) science as a basic area of study, one that needs to be taught and assessed effectively in *all* public schools at *all* levels of a learner's development.

The 1978 *Science Framework* sets forth, in Chapter 3, a balanced, coherent set of science education goals and objectives. Four major goals are identified:

> The goals for science instruction are described under the following categories: (1) achieving scientific attitudes; (2) achieving rational and creative thinking processes; (3) achieving manipulative and communicative skills; and (4) achieving scientific knowledge.[1]

The *Science Framework* also lists many examples of behaviors that could serve as evidence of the learner's progress toward the objectives. In developing this *Addendum,* the authors made the assumption that the reader would have a copy of the *Science Framework* and would be thoroughly familiar with Chapter 3. Without this familiarity there is risk of misinterpreting what follows.

The intent of this part of the *Addendum* is to expand and reorganize the *Science Framework's* goals and objectives into a model that school districts may use to develop their own integrated statements of expectations for learners in science. It is *not* the intent of this *Addendum* to prescribe a specific set or sequence of topics or any one principle of curriculum organization (see pages 12—14 of the *Science Framework*). Nor is it the intent to espouse any one particular system of instruction or evaluation of achievement (see Chapter 4 of the *Science Framework*). It *is* the intent to assert that certain science concepts and skills are basic to scientific literacy—to a rational understanding of ourselves and our surroundings—and that these concepts and skills need to be addressed appropriately at several developmental levels. It is also vital that the development of attitudes and values, rational thinking processes, and manipulative and communicative skills *should take place in close association with* the development of concepts.

Four criteria have been applied in selecting science concepts, thinking processes, and skills for inclusion in this model of expectations:

1. Importance to most learners
2. Appropriateness to learners' developmental levels
3. Teachability
4. Assessability

Unfortunately, none of these criteria embodies an absolute, unarguable standard for its application. All of them require judgment. The judgments reflected in this statement of expectations are those of the committee that developed it, modified to some extent by feedback from the many scientists, teachers, and others who reviewed it. These judgments are concurred in by the Curriculum Development and Supplemental Materials Commission in recommending and by the State Board of Education in adopting and authorizing publication of this *Addendum.* Further judgments will need to be applied by those in school districts that use and adopt this model.

Because most California schools are organized into grade levels, four overlapping grade-level blocks—kindergarten through grade three, grades three through six, grades six through nine, and grades nine through twelve—have been used in this model to approximate students' developmental levels. The concepts have been organized according to broad disciplines of science—life science, physical science, and earth science—with an introductory section on the nature of

[1] *Science Framework for California Public Schools, Kindergarten and Grades One Through Twelve.* Sacramento: California State Department of Education, 1978, p. 25.

science and technology as these fields relate to individuals and society. This method of organization, with all of its shortcomings, still has the advantage of familiarity. Again, one should not infer that this method is the best or only way to organize science concepts in the curriculum or that knowledge must provide the structure around which the curriculum is organized.

The processes presented in the *Science Framework* and this *Addendum* are descriptors of the more important learning processes. They are described in a way that is compatible with Bloom's taxonomy,[2] Guilford's model of the intellect,[3] and Piaget's developmental theory.[4] The processes are sequential, and each is inclusive of the previous processes. For example, one cannot *organize* objects or data without making *comparisons*, and one cannot *compare* without making *observations*.

Because of the sequential arrangement, each process is introduced at the most appropriate level of cognitive development. For example, *applying* is introduced at a level where the mind of the individual student can bring acquired knowledge and experience together so as to invent, create, or put ideas to use. *Applying* is not used in the sense of pointing out applications of scientific principles (e.g., the microscope is an instrument that makes use of principles pertaining to light passing through lenses). Similarly, the process of *inferring* is not simply the realization that "if I release this rock, it will fall to the ground." *Inferring* as a cognitive process is the mind's ability to bring together a variety of pieces of information gathered from experimental and observational data in such a way that a prediction can be stated or a scientific principle can be phrased. (See the summarizing chart, page 4.)

Science Concepts and Processes by Grade Level

It is important to understand the system that has been used here to assign science concepts and processes to grade-level blocks. The concepts and processes have been organized into categories that are described in the paragraphs that follow.

Grade Levels Kindergarten Through Grade Three: Static-Organizational Principles

This grade-level block contains statements of knowledge which help one to observe, communicate, compare, and organize material objects in the universe. The grouping is largely *organizational* in character and correlates well with two of Piaget's stages of cognitive development: the preconceptual stage (two through four years) and the stage of intuitive thinking (four through seven years). To a great extent the knowledge statements in this grouping are representative of concepts that may be symbolized by single words (e.g., bird, solid, star, and so forth). The key processes which a learner must experience concretely to understand and use this knowledge include observing, communicating, comparing, and organizing.

Criteria for Statements in This Grade-Level Block

1. The statement must describe an idea based on a direct human experience with natural objects.
   a. The emphasis here is on the actual physical objects and their properties (e.g., color, size, shape, and texture).
   b. One defines the object as a member of a class and specifies the attributes of the class found in that object. There are two types of definitions used, class and functional.
2. The statement must describe an idea that may exist at various levels of cognitive complexity (e.g., making gross discriminations or fine discriminations; sorting objects on the basis of resemblance or multiple classifications).
3. The statement must be useful as a tool to identify, compare, and organize objects.

Examples of Statements in This Grade-Level Block

1. Sea water is salty. Water in most lakes and rivers is not salty (definition: class).
2. Flowers produce seeds that grow into new plants (definition: function).
3. Machines are devices that make some tasks easier (definition: function).

Grade Levels Three Through Six: Active-Relational, Interactive Principles

This grade-level block contains statements of knowledge which help one to understand the interactions and interdependence of systems of objects.

This grouping is largely relational in character, and it correlates well with Piaget's state of concrete operations (seven through eleven years), because such statements require the coordination of more than one thought. To a great extent the knowledge statements in this grouping are representative of principles, generalizations, and laws. The key processes which a learner must experience to understand and use this knowledge include: observing, communicating, comparing, organizing, and relating.

[2] *Taxonomy of Educational Objectives: The Classification of Educational Goals—Handbook I: Cognitive Domain.* Edited by Benjamin S. Bloom. New York: David McKay Company, Inc., 1956.

[3] Joy P. Guilford, *The Nature of Intelligence.* New York: McGraw-Hill Book Co., 1967.

[4] Jean Piaget, *Science of Education and Psychology of the Child.* New York: Viking Press, 1970.

Criteria for Statements in This Grade-Level Block

1. The statement must describe an idea based on a direct human experience with natural objects.
   a. The emphasis here is on the relationship between objects and the existence of phenomena (e.g., expansion, contraction, evaporation, and so forth).
   b. The existence of a phenomenon is implied when objects are changed because of an interaction between two or more objects.
2. The statement must describe an idea that may exist at various levels of cognitive complexity.
3. The statement must help the learner to see relationships and to make interpretations.

Examples of Statements in This Grade-Level Block

1. A force is a push or pull (relational).
2. Cold-blooded animals have body temperatures that vary somewhat with surrounding temperatures (relational).
3. Heat changes water from a liquid into a gas (interactive).

Grades Six Through Nine: Explanatory-Predictive, Theoretical Principles

This grade-level block contains statements of knowledge which help one to explain phenomena through perceived changes in objects. The grouping is largely theoretical in character, and it correlates with Piaget's period of formal operations (eleven years and older). To a great extent the knowledge statements in this grouping are representative of ideas that are not directly observable. The processes a learner must experience to understand this knowledge include observing, communicating, comparing, organizing, relating, and inferring.

Criteria for Statements in This Grade-Level Block

1. The statement must describe an idea that goes beyond direct human experiences with natural objects and phenomena.
   a. The emphasis here is on inferential judgments that help to explain phenomena.
   b. The explanation of a phenomenon is inferred when objects are changed.
2. The statement must explain an idea that may exist at various levels of cognitive complexity (e.g., the atom: Greek model, Dalton model, or Bohr model).
3. The statement must help one to explain phenomena and make predictions.

Examples of Statements in This Grade-Level Block

1. Matter is composed of tiny particles that are in constant motion. In many substances these are called *molecules* (inference).
2. Characteristics of mineral crystals are consequences of the way their atoms are bonded together in geometric patterns (inference).
3. When male and female sex cells combine in sexual reproduction, equal numbers of genes from each parent determine the characteristics, including the sex, of the offspring (prediction).

Grades Nine Through Twelve: Usable-Applicational Principles

This grade-level block contains statements of knowledge which pertain to ways of using information primarily to obtain further knowledge. This grouping is largely applicational in character, and it correlates with Piaget's period of formal operations (eleven years and older). To a great extent the knowledge statements in this grouping are representative of inventions and technology. Many statements may be concepts, principles, generalizations, and laws which are rephrased to suggest usage. The key processes learners need to understand and apply this knowledge include observing, communicating, comparing, organizing, relating, inferring, and applying.

Criteria for Statements in This Grade-Level Block

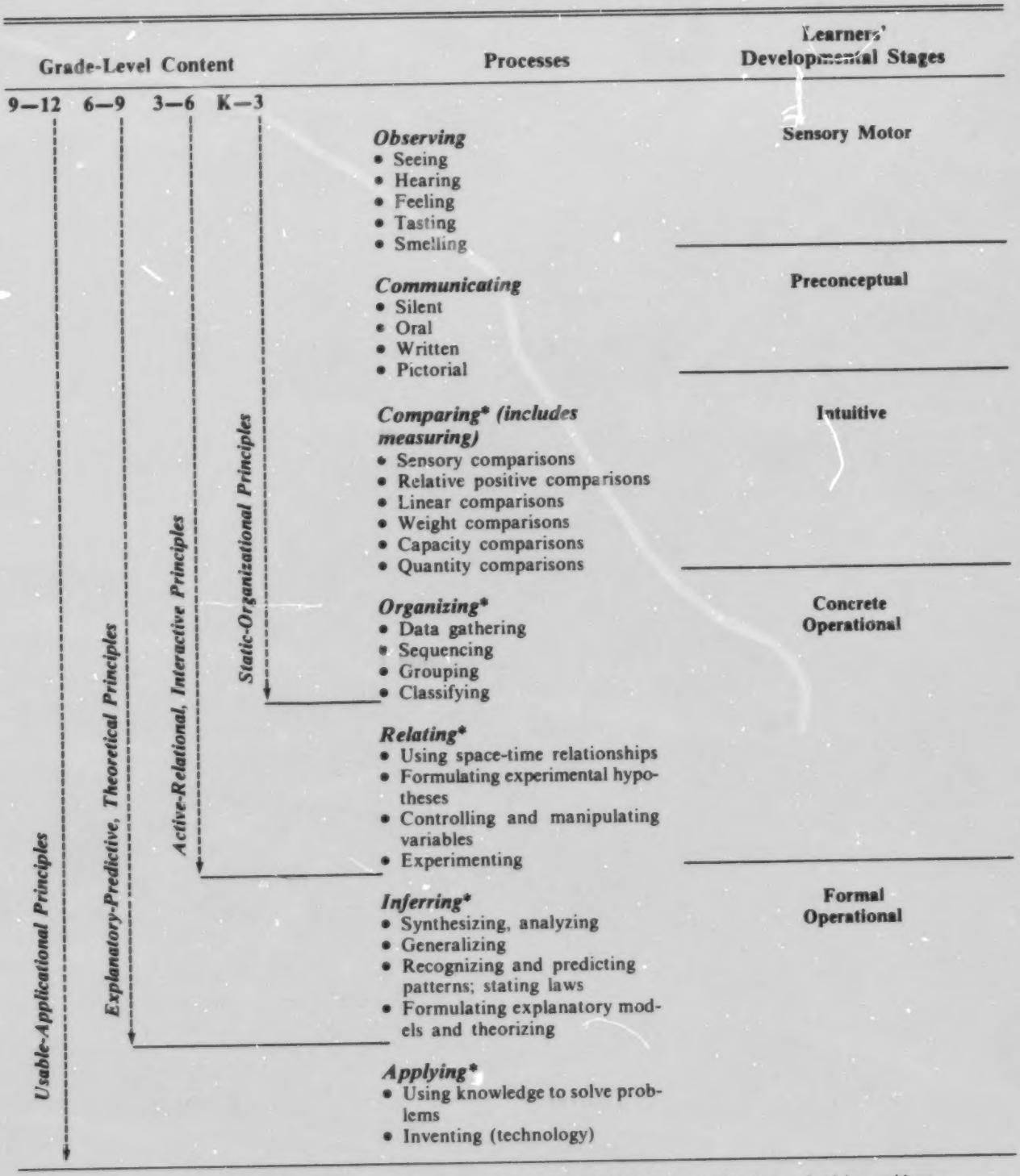
1. The statement must describe an idea based on a direct human experience with natural objects or phenomena.
   a. The emphasis here is on applying ideas in order to help humans or to gather additional knowledge.
   b. It is possible to apply ideas through creative usage or through invention of technological apparatus.
2. The statement must describe an idea that may exist at various levels of cognitive complexity.
3. The statement must be useful in application or in obtaining further knowledge.

Examples of Statements in This Grade-Level Block

1. Selective breeding of plants and animals that have desirable characteristics can cause these characteristics to occur more frequently in offspring (usage).
2. Use of the oceans and ocean resources is a focus of international conflict as well as international cooperation (usage).
3. The development and use of more efficient lighting sources is one way of conserving energy (e.g., fluorescent versus incandescent) (invention-usage).

The correlation of science knowledge and processes with developmental levels and grade levels is summarized on the "Chart Summarizing Science Process/Content and Developmental Stages," page 4.

Chart Summarizing
Science Process/Content and Developmental Stages



*These processes include the application of appropriate mathematical concepts and skills in interpreting data and solving problems.

Descriptions of Processes Shown on the Chart

Observing

The main route to knowledge is through *observing*, using all the senses. This process is a distinct one by which people come to know about the characteristics of objects and their interactions.

Communicating

Objects are named and events are described by people so that they can tell others about them. *Communicating* is a fundamental human process that enables one to learn more about a greater range of information than could be learned without this process.

Comparing

Comparing is a distinct process by which people systematically examine objects and events in terms of similarities and differences. By comparing the known to something unknown, one gains knowledge about the unknown. All measurements are forms of comparing.

Organizing

Knowledge of principles and laws is gained only through the systematic compiling, classifying, and ordering of observed and compared data. Bodies of knowledge grow from long-term *organizing* processes.

Relating

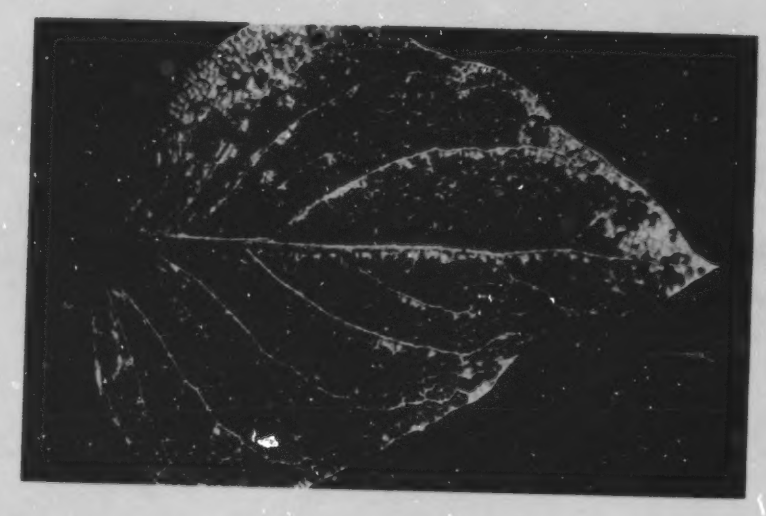
Relating is a process by which concrete and abstract ideas are woven together to test or explain phenomena. Hypothetical-deductive reasoning, coordinate graphing, the managing of variables, and the comparison of effects of one variable on another contribute to the attainment of the major concepts of science.

Inferring

The process of realizing ideas that are *not* directly observable is the process of *inferring*. The process leads to predictive explanations for simple and complex phenomena.

Applying

Use of knowledge is the *applying* of knowledge. Inventing, creating, problem-solving, and determining probabilities are ways of using information that lead to gaining further information.



Suggestions and Cautions in Using the Model

An important assumption underlying this model statement of expectations is that we should not waste valuable time and resources trying to teach science concepts and processes that are beyond the developmental readiness of most students. Thus, in developing a curriculum for kindergarten through the third grade, one reasonably might draw the content from the kindergarten through third grade section of this model, with the possible inclusion of some ideas and processes from the third through sixth grade section. *In developing a ninth through twelfth grade curriculum, on the other hand, it will be necessary to reinforce concepts, processes, and skills from the sixth through ninth grades, third through sixth grades, and even the kindergarten through third grade sets of expectations.*

Attitudes and Science Concepts

In the field review draft of the *Addendum*, an attempt was made to correlate specific attitudes and career opportunities with specific science concepts, processes, and skills. Feedback from reviewers indicated that this attempt was not very successful. Most of the attitudes set forth in the *Science Framework* can be developed in connection with *any* science concepts listed here. Likewise, most of the numerous career opportunities that could be cited relate to many concepts. In response to recommendations from reviewers, the attitudinal objectives from the *Science Framework* are included here for ready reference as follows:

Goal: To develop values, aspirations, and attitudes that promote the individual's personal involvement with the environment and society[1]

Objectives: The learner:

- Shows curiosity about objects and events
- Shows an awareness of and responds in a positive manner to beauty and orderliness in the environment
- Appreciates and respects all living organisms (including self) and their place in the environment
- Takes an active role in solving social problems related to science and technology
- Weighs alternative scientific, economic, psychological, or social factors when considering possible resolutions to some problems
- Organizes and reports the results of scientific investigations in an honest and objective manner
- Shows a willingness to subject data and ideas to the criticism of peers
- Has a critical, questioning attitude toward inferences, hypotheses, and theories
- Habitually applies rational and creative thinking processes when trying to find relationships among seemingly unrelated phenomena and when seeking solutions to problems
- Gives attention to and values science as an endeavor of human beings from all racial, ethnic, and cultural groups
- Considers science-related careers and makes realistic decisions about preparing for such careers, taking into account the abilities, interests, and preparation required

The section in this *Addendum* entitled "Ethical Issues in the Science Classroom" offers guidelines related to the development of students' attitudes. Ethical concerns (EC) highlighted in the model suggest points at which attitudes of personal and social responsibility can be developed. Career opportunities and contributions to science by men and women of various races and ethnic backgrounds are dealt with in the initial section of the model entitled "Science, Technology, Individuals, and Society."

Thinking Processes and Skills

The processes and skills juxtaposed with specific concepts in this model are intended to describe what students should be able to do as a result of instruction, not activities that would bring about such learning. In some cases the processes and skills *imply* classroom activities, but *no attempt has been made to list specific learning activities* that can be used to teach the concepts, processes, and skills. A rich variety of such learning activities is described in science education sourcebooks, curriculum project materials, teacher editions of textbooks, journals of science, teacher organizations, and the like. The task of identifying learning activities, along with the tasks of determining sequence and selecting instructional materials and instruments for evaluating learner achievement, will need to be addressed in the process of curriculum development at the local district level.

Performance criteria have not been included in this model, nor have the expectations necessarily been phrased in behavioral terms. Some specific criteria and behaviors are implicit in the skills expectations. Examples of others may be found in Chapter 3 of the *Science Framework*. A variety of evaluation techniques are also discussed and related to specific objectives in Chapter 4 of the *Science Framework*.

Expectations for Learners

It is assumed that the learning and performance in science of many high school students will go substantially beyond the expectations set forth in this model. Expectations for college preparatory courses in chemistry, physics, and advanced life and earth sciences have not been included in this *Addendum* because they

[1] See pages 26–29, 57, and 62–65 of the *Science Framework* for amplification of these objectives and suggestions about teaching toward them and evaluating their attainment.

apply to only a fraction of high school students, not to all. Even so, it is anticipated that some of the concepts and processes outlined here—those requiring the highest levels of formal operation—may prove to be beyond the mastery of some students. The position taken here is that all students should be given opportunities to develop formal thinking capabilities in science along the lines proposed in the model. While the expectations may turn out to be unrealistic for some students, there will be others who will achieve at higher levels than they might have if the challenge had not been provided. Our reach should exceed our grasp.

Illustration of How to Use the Model

The following example from page 55 shows how "Expectations for Learners' Achievement in Science—A Model" is put together and may assist in the use of this section of the *Addendum*.

Earth Science—Meteorology

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9	
Stormy weather is usually associated with low atmospheric pressure; fair weather, with high pressure.	*Observing, Communicating, Comparing, Organizing, and Relating*
Learners should be expected to demonstrate an understanding of this concept.	Use a set of meteorologic instruments to keep records of temperatures, air pressure and movements, humidity, precipitation, and other weather observations.
(TA) Weather predictions are based on this concept.	This is a statement of how learners should be expected to apply thinking processes and skills to the concept.
Learners should be expected to demonstrate an understanding of this or similar technological applications of the concept.	
(EC) All human activities that pollute the air are of concern to individuals and society.	Learning activities (not specified in this model) could include:
Learners should be expected to demonstrate an understanding of this ethical concern and its relationship to concepts in meterology. Opportunities should be provided for learners to incorporate this concern into their system of values and process of decision making and behavior.	Design and use of weather data charts Reference to weather data reported in newspapers Use of videotapes of satellite weather pictures Construction and placement of weather instruments Comparison of data gathered by different individuals Discussion of the importance of weather forecasting to agriculture, air travel safety and convenience, and so forth

Science, Technology, Individuals, and Society

The content area "Science, Technology, Individuals, and Society" is to be treated in a special way. The intentions are to help students understand how science works, how it can be useful in daily living, and how science and technology affect society. This material is *not* meant to be taught as a separate unit. Instead, the understandings, attitudes, processes, and skills described under this heading should be acquired as students study the other topics appearing in the model. Here are examples illustrating some ways this integration might be accomplished:

Example One: Levels Three Through Six, Biological Science—Plants (See page 22.)

As students study seed germination and the growth of seedlings, they will record both visual data (their sketches) and numerical data (their measurements of plant growth). Throughout this activity they should be taught how to record their data in an objective manner (e.g., accuracy of measurement). A respect for the integrity of such data should be emphasized. For example, data records are not changed, regardless of what "ought to happen" or what we might prefer to see. This example illustrates one of the many ways in which honest and objective reporting of results can be infused into the study of a biological topic.

Example Two: Levels Three Through Six, Physical Science—Energy: Sources and Transformations (See page 72.)

In a study of energy sources and transformations, students in grades three through six should examine a variety of energy-transforming devices used in the home. These inventions, all based on one or another kind of energy conversion, include such devices as radios, toasters, record players, microwave ovens, and television sets. These devices also illustrate ways in which scientific knowledge has made possible a great variety of technological applications.

These kinds of infusions of "Science, Technology, Individuals, and Society" concepts into the biological and physical science segments of this model need to be deliberately built into the science program. The infusion of these concepts will take place only if such planning occurs. The effectiveness of the "Science, Technology, Individuals, and Society" learnings will be seriously jeopardized by attempts to treat them as a separate unit of study. Our past experience with attempts to treat such topics as metric measurement or scientific method as separate units of study has clearly demonstrated the need to treat these types of material within the context of science concepts.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
Scientists study the world around us and try to explain natural objects and events. Some of the things scientists do include careful observing, comparing, communicating, measuring, and organizing information.	*Observing, Communicating* Identify science processes as they are used at home and in the classroom.
Scientists are men and women of many races, nations, and cultural backgrounds.	*Observing, Communicating* Give examples of scientists that include men and women of various races or ethnic groups.
Scientific knowledge is used in ways that affect our daily lives.	*Observing, Communicating* Observe and describe ways in which use of scientific knowledge affects daily life; e.g., consumer products, transportation, communication, health behavior, and recreation.
Scientific knowledge is important in many kinds of work.	*Observing, Communicating* Observe and describe ways in which people use science in their work. Identify from pictures of people working how science is involved.
Men and women of all races and ethnic groups do work that involves science.	

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Scientists look for patterns in what they observe. They develop hypotheses as possible explanations for the way things are; then they develop ways to test these hypotheses.	*Observing, Communicating, Comparing, Organizing, Relating* Identify and describe a pattern or regularity in a series of observations; e.g., variations in temperature or traffic volume at different times of day. Suggest some possible explanations.
Men and women of all races and many nations, ethnic groups, and cultural backgrounds have made, and continue to make, significant contributions to the advancement of science and technology. **(EC)** Honest and objective reporting of results is essential to successful work in science.	*Observing, Communicating* Locate and report on biographical information on the lives of scientists.
Scientific knowledge has made possible a great variety of technological applications; e.g., electronic communications, food preservation, and antibiotics.	*Observing, Communicating, Comparing, Organizing* Identify the more important scientific technological developments in this century. Trace how newer developments depended on earlier ones.
Instruments devised by technologists have greatly broadened and deepened the scope of scientific investigation; e.g., microscopes, telescopes, and computers.	*Observing, Communicating* Identify common pieces of scientific apparatuses and describe their use.
The nature of our society is strongly influenced by science and technology.	*Observing, Communicating, Comparing, Organizing* Compare how we live with the way people live (or used to live) in cultures that have had little impact from science or technology.
Scientific knowledge, thinking processes, and skills are used in a great variety of careers, from mechanics and chefs to farmers and engineers.	*Observing, Communicating, Comparing, Organizing* Observe and describe ways in which specific scientific knowledge being studied is useful to people in their work; e.g., electric circuits, insect life cycles, nutrition, or earthquakes. Observe and describe ways in which science processes and skills being learned are useful to people in their work; e.g., careful observation, comparing, measuring, classifying, organizing information, formulating hypotheses, and experimenting.
Science-related careers are open to men and women of all races, ethnic groups, and national origins.	

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9	
Repeated observations and measurements improve the reliability of data.	
Classification systems are developed to help organize information about objects, organisms, and events. Examples are plant taxonomy, volcanoes, and chemical elements.	*Observing, Communicating, Comparing* Compare and describe systems used to classify items in a supermarket or hardware store with systems used to classify plants and animals.
Unexpected observations often result in new questions for scientific study. Examples are the discovery of penicillin, the planet Neptune, and radioactivity.	
Scientists develop theories or models as a result of observations and experiments to describe the nature of objects and events. These theories and models tend to be modified or replaced with new theories and models as new knowledge is gained. Examples are spontaneous generation, continental drift, and atomic theory.	*Observing, Communicating, Comparing* Describe how a scientific theory explaining something has changed as new knowledge has been gained; e.g., cause and treatment of a disease or motions of stars and planets.
Theories of science are never proven and must be capable of being subjected to tests that could disprove them.	
Scientific laws are generalizations based on many observations. Examples are Mendel's laws and conservation of matter.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* State a "law" based on a series of observations; e.g., birds chirp more in the morning and evening than during other times of the day.
Especially in recent times, advancements in science and technology have often resulted from the cooperative efforts of a number of people rather than from the efforts of one person working alone. Examples are cancer research, space research, and high-energy physics.	*Observing, Communicating, Comparing* Identify and compare some specific scientific or technological advancements made by individuals with those made by teams of people.
Science and technology have been applied to solve human problems and enhance human creativity. Examples are control of diseases, weather forecasting, and development of structural materials.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Identify major scientific or technological advances and how they affect the way people live; e.g., agriculture, use of fossil fuel energy, or electronic communication. Predict how our lives and surroundings would be different if some particular advance had not been made; e.g., electronic communication. Describe how an art form such as music, performing arts, or sculpture has changed in response to advancing scientific knowledge and technological applications.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued)	
Application of science and technology to solve human problems can create other problems. Examples are overpopulation, depletion or pollution of soil, and traffic hazards.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Relate specific scientific or technological advances to problems these advances have solved and to new problems they have created.
Careers related to science and technology vary greatly in the amount and kind of preparation they require.	*Observing, Communicating, Comparing, Organizing* Classify science or technology-related careers according to the extent of the training they require; e.g., high school, technical school, or graduate studies.
Some careers involve the application of science processes to gain new knowledge. Others involve technological applications of science to solve problems; some careers combine both.	*Observing, Communicating, Comparing, Organizing* Classify careers according to whether they involve primarily scientific research, application of technology to solving practical problems, or both.
Many science or technology-related careers require a substantial background in mathematics as well as communication skills.	*Observing, Communicating, Comparing, Organizing* Identify careers requiring substantial preparation in mathematics.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
The systematic, cyclical application of science processes is a powerful way of gaining knowledge about nature. However, individual scientists do not always follow a set pattern in applying science processes.	
Scientific advancement is enhanced by free and open communication among investigators working on a problem and is inhibited when such communication is lacking. For example, the discoveries of Mendel were poorly communicated; those of Galileo were suppressed. Open communication of scientific discoveries is exemplified by the International Geophysical Year.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Identify and describe instances in which advances in science were inhibited by poor communication or facilitated by good communication.
Science has limitations. Not all questions are subject to scientific inquiry.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Identify questions that are not subject to scientific inquiry and explain why.
Many of the processes used by scientists are also effective in other areas of endeavor; e.g., history, economics, sociology, or business.	*Observing, Communicating, Comparing, Organizing* Identify examples of science processes as they are adapted and used by historians, economists, journalists, and so forth.
Processes used by scientists can be applied effectively in making personal decisions.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Select an item (e.g., car, bicycle, or dishwasher) for purchase, using observations and available research data. Use data from scientific investigations to present and support a position on a political issue.
Our society has supported and encouraged scientific and technological advances through such means as education, free enterprise, and direct governmental support of research and development.	*Observing, Communicating, Comparing, Organizing* Describe trends in governmental expenditures for scientific research during the past ten to 20 years; e.g., National Science Foundation (NSF) funding, basic research, or National Aeronautics and Space Administration (NASA) funding for space research.
Our society has held high expectations for what science and technology can do to improve the quality of life and to solve a variety of problems. Sometimes these expectations have been met, and at other times they have proved to be unrealistic.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Identify some major medical problems that might be solved by scientific research and/or technological advancement.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9—12 (Continued)	
Scientific discoveries sometimes have far-reaching consequences to society. Both scientists and the society that determines applications of new knowledge need to weigh possible benefits and hazards and make responsible decisions. Examples of this situation are gene-splicing, weather control, and nuclear energy.	
Advances in science and technology have created numerous new careers in the past and will continue to create new ones in the future.	*Observing, Communicating, Comparing, Organizing* Identify present careers that have come into existence as a result of the application of new knowledge and/or technology.
Intelligent career decision making involves a knowledge of science, technology, social needs and trends, and one's personal abilities and interests.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Predict new careers that could result in the future from the application of new knowledge and/or technology. Identify careers of personal interest and describe them in terms of (1) how they relate to science and technology; (2) what preparation they require; (3) what personal characteristics they require; (4) what rewards and satisfactions they offer; and (5) how future developments may affect them. Identify a variety of sources of information about careers involving science (e.g., a newspaper's classified advertising section, people, or library resources).

Biological Science—Cells, Genetics, and Evolution

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

K–3

Living things have characteristics by which they can be described and distinguished from nonliving things. They take in food, give off wastes, grow, respond to stimuli, and reproduce their own kind.[1]

Observing, Communicating, Comparing, Organizing

Observe a variety of objects and organisms and sort them as living or nonliving.

There is great diversity among living things.[1]

Observing, Communicating, Comparing

Observe and describe a variety of living things, noting similarities and differences.

The many different kinds of living things have characteristics and behaviors by which they can be described, identified, sequenced, and classified.[1]

Observing, Communicating, Comparing, Organizing

Classify animals according to a variety of characteristics (one at a time); e.g., food eaten, body covering, appendages, or habitat.

Most living things are made up of smaller structures that can be seen with a hand lens or a microscope.[1]

Observing, Communicating

Use a hand lens to examine and describe a variety of parts of living things; e.g., leaves, fingers, or insect wings.

The most widely used system of classification has three broad categories for living things: plants, animals, and protists.[1]

Observing, Communicating, Comparing, Organizing

Observe specimens or pictures of plants, animals, and protists, and describe characteristics that cause them to be classified as such.

[1]These concepts are also developed under "Biological Science—Plants," "Biological Science—Animals," "Biological Science—Protists," and "Biological Science—Human Beings."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Living things have adaptations that enable them to live in their particular habitats.[1]	*Observing, Communicating, Comparing, Organizing, Relating* Observe and describe characteristics and behaviors of organisms, including humans, that live in different environments; e.g., desert, pond, tidepool, estuary, or meadow. Suggest how the characteristics and behavior adapt the organism to the environment. Demonstrate proper care of living organisms.
A species is a kind of living thing whose individuals have many similarities and can reproduce their own kind.[1]	*Observing, Communicating, Comparing, Organizing* Define the term *species* and give examples of several species of animals, plants, and protists.
Variations exist among individuals of a species.[1]	*Observing, Communicating, Comparing, Organizing* Observe and describe similarities and differences among several members of a species (e.g., cats, dogs), and make a chart of the physical characteristics (size, coat, color, and temperament) that indicate variation in a species.
Living things are made up of a cell or cells that can be seen with a microscope.[1]	*Observing, Communicating* Examine prepared slides of plant or animal tissues, and draw illustrations of several of the cells observed.
Most cells have a nucleus (other than those of some protists), an outer coating, and other tiny structures.	*Observing, Communicating, Comparing, Organizing* Draw a typical cell, and label the parts, including the nucleus, cell wall or membrane, and other structures.
Similar specialized cells form tissues. Tissues form organs that perform specific functions. Organs are grouped into systems that perform functions in complex organisms.[1]	*Observing, Communicating, Comparing, Organizing* Observe and describe tissues and organs of plants and animals, and relate the organs to systems and their functions.
When an organism dies, its life functions cease, and its body begins to disintegrate.	*Observing, Communicating, Comparing, Organizing, Relating* Examine living and no longer living organic materials in a particular environment; e.g., top soil, forest floor, meadow, or swamp. Describe how these materials relate and contribute to the life cycle. Observe and describe what happens to a dead organism over a period of time.

[1]These concepts are also developed under "Biological Science—Plants," "Biological Science—Animals," "Biological Science—Protists," and "Biological Science—Human Beings."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—8 (Continued)	
Fossils are formed when plants, animals, and microorganisms are buried in sediments, absorb minerals, and leave their imprints or actual remains in sedimentary rocks.[2]	*Observing, Communicating* Observe and describe fossils of various organisms. *Observing, Communicating, Comparing, Organizing, Relating, Inferring* Describe how fossil imprints were made, and simulate this process by making impressions of seashells, leaves, or footprints in plaster of paris or clay.
Fossil remains indicate that many species have become extinct and that new species have come into being over geologic time.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Examine specimens or pictures of fossil evidence of prehistoric life. Describe how some characteristics and behaviors of these creatures can be inferred from the fossil evidence and by their resemblance to existing species.

[2]Closely related concepts are developed under "Earth Science—Geology and Natural Resources."

6–9	
The complex structures and processes that characterize living things require energy to grow and maintain them.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe and gather information about energy sources for various living things; e.g., sunlight, food/oxygen, food without oxygen (fermentation), and so forth. Predict what will happen to an organism when its energy source is cut off. Demonstrate the proper care of living organisms, or observe others caring for animals.
Genes are materials in cell nuclei that determine the characteristics of organisms. They are located in bodies called chromosomes. When a cell divides (mitosis) or an organism reproduces asexually, the genes and characteristics of the new cells are usually just like those of the parent cell or organism.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Illustrate the stages of cell division. Compare the structures of the genes and chromosomes of the parent cells with those of the new cells, and predict the characteristics of the new cells.

[1]Closely related concepts are developed under the other sections of biological science and "Physical Science—Energy: Sources and Transformations."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
8—9 (Continued)	
Meiosis, cell division in which only half of the genes go to each daughter cell, occurs in the production of sex cells.	*Observing, Communicating, Comparing* Use a microscope to observe and describe the similarities and differences between meiosis and mitosis.
When male and female sex cells combine in sexual reproduction, equal numbers of genes from each parent determine the characteristics, including the sex, of the offspring.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use library or text references to compare and contrast sexual and asexual reproduction. Cite the advantages of each to the species.
Dominant traits can be inherited through the genes of either or both parents; recessive traits need to be in the genes of both parents to be expressed. Chance pairing of genes, multiple genes, and incomplete dominance are mechanisms that contribute to the uniqueness of each offspring.	*Observing, Communicating, Comparing, Organizing* Use Punnett squares to show all the offspring possible of a single dominant/recessive characteristic with given parental characteristics.
Mutations are changes in genetic material that occur occasionally. When mutations occur in sex cells, the offspring may have new characteristics.	*Observing, Communicating, Comparing, Organizing* Use library and research skills to prepare a report on common mutations and their effects on humans, other animals, and plants.
Some mutations are lethal, most are harmful, some are neutral, and a few help the organism adapt to its environment and increase its chance of surviving and reproducing. (TA) Radiation-induced sterility is used for insect control.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Collect data on mutations, and prepare a chart grouping them into three categories: harmful, neutral, and beneficial.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued) Natural selection is the process through which beneficial changes in characteristics that come about through variation and mutation tend to persist over generations, while harmful characteristics and changes tend to be eliminated.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Collect data on changes through beneficial mutations and variations, and infer the kind of environmental conditions that may have contributed to the present characteristics.
Relative ages of fossils are determined in several ways, including the order in which the strata of sediments that contain them were deposited.[2]	
The study of fossils and the rocks that enclose them provides information about populations of extinct organisms and the environmental conditions in which they lived.	
The dating of fossil remains of plants, animals, and microorganisms reveals a progression in time from simpler to more complex forms, suggesting that complex species have evolved from simpler ones. Such evidence indicates the appearance of simple life forms on earth between three and four billion years ago. Natural selection is believed to be a major process contributing to the evolution of life forms.[2]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Compare fossils representative of different geological periods to infer the progression from simple to complex life forms.

[2]Closely related concepts are developed under "Earth Science—Geology and Natural Resources."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
Cytoplasm contains organelles that perform specific cell functions; e.g., production of enzymes, metabolism of food, and removal of wastes.	*Observing, Communicating* Use a microscope to observe and describe living microorganisms.
The cytoplasm inside cells consists largely of water and proteins.	*Observing, Communicating, Comparing, Organizing, Relating* Conduct appropriate tests to verify the existence of proteins and water in cells.
DNA (deoxyribonucleic acid) is the genetic material in chromosomes that contains the coded information or pattern that determines the characteristics of the cell and of the organism.	
DNA gives rise to RNA (ribonucleic acid), a working copy that serves as a pattern for producing proteins in the cell.	
Enzymes, or proteins, are large complicated molecules: long twisting chains that are composed of 20 different kinds of smaller molecules called amino acids.	*Observing, Communicating, Comparing, Organizing* Use library references to report on the characteristics and functions of enzymes, protein, and/or amino acids. Prepare models of enzymes/proteins with amino acids as building blocks.
Enzymes serve as catalysts to promote essential chemical reactions in cells.	
(TA) Enzymes are used in many laboratory and industrial processes.[1]	
Mutations are changes in DNA caused by radiation, certain chemical substances called mutagens, and other causes not yet understood. Mutagens are found in some drugs, some food substances, and cigarette smoke. Some mutations may take place spontaneously.	*Observing, Communicating, Comparing, Organizing* Conduct and report on research regarding the effects of temperature, chemicals, and radiation on fruit fly mutations.
(EC) Control of mutagenic substances and dealing with their effects are matters of both social and individual concern.	
(TA) Gene-splicing is artificial modification of DNA molecules, a process which produces new or modified characteristics or organisms.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Conduct library research to report on DNA recombination, giving historical examples and describing the benefits and hazards of a hypothetical microorganism.

[1]Closely related concepts are developed under "Physical Science—Matter."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9—12 (Continued)	
(TA) Gene-splicing offers hope of controlling genetic diseases and disorders and of creating organisms with desirable characteristics; it could also be misused to develop harmful microorganisms.	
(EC) Benefits and hazards of gene-splicing both involve ethical decisions.	
Greater variation is possible with sexual than with asexual reproduction.	*Observing, Communicating, Comparing, Organizing, Relating* Formulate the different possible combinations of two heredity characteristics for offspring of parents through sexual reproduction, and compare the result with an example of asexual reproduction.
(TA) Selective breeding of plants and animals that have desirable characteristics can cause these characteristics to occur more frequently in offspring.	*Observing, Communicating, Comparing, Organizing* Report on careers in animal and plant husbandry and the preparation necessary to enter the field. Report on how selective breeding has been useful to people.
(EC) Applications of selective breeding to humans involve serious ethical problems.	
Analysis of DNA molecules that perform similar functions in different species reveals degrees of difference among those molecules that correlate with degrees of difference among the species. This observation suggests a process of evolution of species from other species that correlates well with fossil records. The system commonly used by scientists to classify living things is closely related to patterns of evolutionary development inferred from such evidence.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Compare data describing the structure of genetic materials of closely and distantly related species, and explain how divergent patterns of evolution over geologic history are inferred from such evidence.

Biological Science—Plants

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
Most plants grow in soil.	*Observing, Communicating, Comparing* Observe and describe a variety of growing plants, and determine whether or not most grow in soil.
All plants need water.	*Observing, Communicating* Observe and describe what happens to plants that are deprived of water.
Growth and reproduction of plants are affected by temperature.	*Observing, Communicating* Observe and describe what happens to a plant placed near a heater or in direct sunlight.
Plants do not tolerate extremes in temperatures.	*Observing, Communicating, Comparing* Observe and compare three similar plants, one placed in a hot environment, one in a cold environment, and one in a moderate environment (e.g., classroom temperature).
Green plants need light.	*Observing, Communicating, Comparing* Observe and describe what happens to a plant grown in the dark. Compare it with similar plants grown in normal light.
Many kinds of green plants have roots, stems, leaves, and flowers.	*Observing, Communicating, Comparing, Organizing, Relating* Collect a variety of plant parts (seeds, roots, stems, flowers, and leaves) to see which can be used to produce new plants.
Flowers produce seeds that grow into new plants.	*Observing, Communicating* Collect illustrations of flowering plants and make a display of them. Observe plants grown from actual fruits; e.g., beans, avocados, or citrus.
Ferns and mosses are simple green plants.	*Observing, Communicating, Comparing* Observe and describe some ferns and mosses, and compare them with flowering plants.
Plants can be grown for use and enjoyment.	*Observing, Communicating, Comparing, Organizing* Observe and identify the parts of plants eaten for food or used for fiber. Describe and demonstrate proper care of plants.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Most plant cells differ from most animal cells in that they have a thicker, stronger outer coating called a cell wall. (TA) Plant fibers are used for fabrics, building materials, and the like.	*Observing, Communicating, Comparing* Use a microscope to observe, describe, and compare plant and animal cells.
Soils provide the water and minerals that plants need.[1]	*Observing, Communicating, Comparing, Organizing* List the materials in soil that plants need.
Plants have adaptations that enable them to obtain and store water, produce and store food, protect themselves against predators and parasites, receive sunlight, minimize the effects of extreme temperatures, reproduce, and so forth.	*Observing, Communicating, Comparing, Organizing, Relating* Observe and describe different adaptations that are protective features of a plant. Demonstrate proper care of plants.
Roots anchor plants and absorb minerals and water from soil. Some roots store food. Roots help hold soil in place.[1]	*Observing, Communicating* Observe and draw pictures of the root formation of plants growing in a container of water.
Stems support plants and transport their fluids.	*Observing, Communicating, Comparing, Organizing, Relating* Assemble the necessary materials and apparatus; then investigate and describe a celery stalk's vessels for transporting liquids.
Leaves absorb sunlight and produce the plant's food.	*Observing, Communicating, Comparing, Organizing* Make a chart identifying each major part of a leaf and the function of each part.
Chlorophyll, the green matter in plants, enables plants to absorb sunlight and produce food.	*Observing, Communicating, Comparing, Organizing* Use library and classroom reference materials to investigate photosynthesis and the role of chlorophyll in the process.

[1]This concept is also developed under "Earth Science—Geology and Natural Resources."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—6 (Continued)	
Flowers are plants' reproductive organs, producing male and female sex cells that can unite and develop into seeds that develop into new plants.	*Observing, Communicating, Comparing, Organizing, Relating* Dissect a typical flower; then draw and describe the function of each part.
Seeds require certain conditions, such as proper temperature and moisture, in order to germinate. (TA) The controlling conditions in a plant nursery speed the growth of plants.	*Observing, Communicating, Comparing, Organizing, Relating* Test and compare seeds grown under different conditions.
	Observing, Communicating, Comparing, Organizing Prepare a sequence of illustrations showing the changes that take place during the germination of a bean seed.
Some flowering plants can reproduce asexually from vegetative parts such as roots and stems. (TA) Grafting is used commercially to reproduce plants.	*Observing, Communicating, Comparing, Organizing* Make a chart showing different ways various flowering plants can reproduce. Propagate a plant from a cutting.
Ferns have roots, stems, and leaves. Mosses have stems and leaves.	*Observing, Communicating, Comparing* Examine ferns and mosses; then draw illustrations comparing them structurally with flowering plants.
(TA) Agriculture is the systematic growing of plants and animals for use as food, fiber for clothing, building materials, ornamental use, and so forth.	*Observing, Communicating, Comparing, Organizing* Prepare a list or collage of pictures illustrating major products that are derived from plants.
6–9	
Roots absorb water by a process called osmosis, in which a membrane allows diffusion of some molecules from where they are more concentrated (in the soil) to where they are less concentrated (in the roots). Minerals are absorbed by diffusion or active transport.[1]	*Observing, Communicating, Comparing* Use a microscope to observe and compare the thickness of the cell walls of root tips and root hairs with those of other parts of the roots.
Attraction of water molecules to each other (cohesion) and to the walls of thin tubes in plant stems (adhesion) causes water and dissolved minerals to rise up to the leaves, where some water evaporates and some is used in food production.[1]	*Observing, Communicating, Comparing, Organizing* Sequence the travels of a molecule of water through a plant, from the soil to evaporation from the leaves.

[1]Closely related concepts are developed under "Physical Science—Matter."

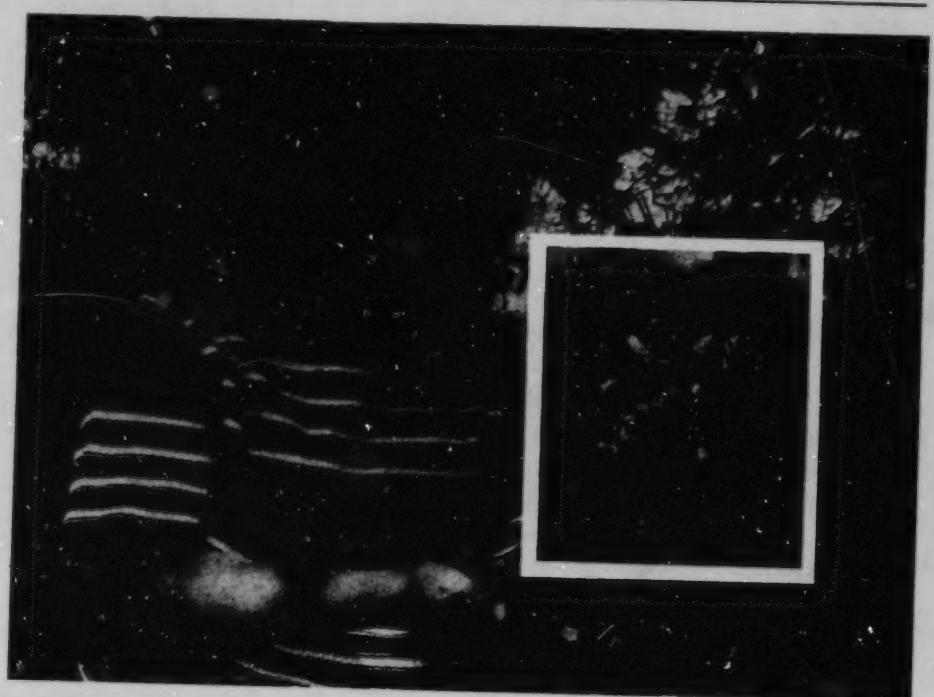
Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued)	
To grow and maintain life processes, plants metabolize some of the food they produce. In doing so, they produce carbon dioxide, water, and other products.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Measure and compare the oxygen/carbon dioxide production of a water plant during the day (light) and at night (dark) and hypothesize regarding the photosynthesis/metabolism balance in different light conditions.
Compounds of nitrogen, phosphorus, and potassium as well as small amounts of many other elements are essential to plant growth and reproduction. (TA) Fertilizers are used extensively to improve crop yields.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Experiment with groups of plants in sterile soil media by feeding them different trace elements to determine which are essential to plant growth.
When dead plant material, dead animal material, and waste products fall to the ground, minerals essential for plant growth are returned to the soil. (TA) Partially decomposed plant and animal material in organic fertilizers such as compost improves the growth of plants.	*Observing, Communicating, Comparing, Organizing, Relating* Compare the growth of plants in soils that contain and do not contain organic materials. Demonstrate the proper care of plants.
Photosynthesis renews oxygen to the atmosphere and to bodies of water while using up the waste products of plant and animal metabolism.[2]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use reference materials to compare the daily oxygen use of an average human and the oxygen production of a common green plant. Calculate the number of such plants necessary to support the oxygen needs of the people in the United States.
Most atmospheric oxygen comes from oceanic diatoms.[2]	
[2]This concept is also developed under "Biological Science—Ecosystems" and "Earth Science—Oceanography."	

9–12

In leaves and other green parts of plants, carbon dioxide, water, and minerals are converted into sugars and amino acids. Starch, cellulose, proteins, vitamins, and other food substances are subsequently produced.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Experiment to compare the starch content of leaves maintained in sunlight with those shielded from light (safety precautions).
The first microorganisms and plants are believed to have evolved in an atmosphere containing almost no oxygen. Production of oxygen by photosynthesis made the evolution of aerobic organisms possible.	*Observing, Communicating, Comparing, Organizing* Describe experiments that have been made to test the possibility of producing simple organic compounds in a primitive environment. Report on anaerobic organisms such as botulism and tetanus bacteria.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12 (Continued)	
(TA) Some essential plant nutrients can be added to soil in the form of natural or synthetic chemical fertilizers.[1]	*Observing, Communicating, Comparing, Organizing* Prepare a report comparing the production and use of natural and synthetic fertilizers.
(EC) Both maintenance of soil fertility and problems associated with use of chemical fertilizers are science-related social problems.[1]	
Bacteria harbored in the roots of plants, called legumes, convert nitrogen from the air into compounds that plants can use. (TA) crop rotation is an application of this phenomenon.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Compare the food content of legume food products with other plant foods, and generalize regarding the overall value of legumes to the food industry.
Ferns and mosses reproduce both asexually, with spores, and sexually, sometimes alternating generations in their method of reproduction.	
(TA, EC) Control of insects, other pests, and plant diseases by chemical and biological means may increase agricultural productivity, but the effects on the environment may be undesirable.	

[1]This concept is also developed under "Earth Science—Geology and Natural Resources."



Biological Science—Protists

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Fungi are simple plant-like organisms that live off plants or animals, waste products, or rotting material; e.g., molds, mushrooms, or yeast. (TA) Fungi are used in fermentation processes, such as cheesemaking.	*Observing, Communicating* Observe and describe the characteristics and growth of common fungi such as molds and mushrooms (safety precautions).
Algae are simple plant-like organisms that live in water. Some are very tiny, while others, like seaweed, grow quite large. (TA) Algae can be farmed for use as food or as raw materials for manufacturing.	*Observing, Communicating, Comparing* Observe, describe, and compare common aquarium and ocean algae.
6–9	
Included among the protists, living things that are not easily classified as plants or animals, are protozoa, bacteria, fungi, and algae.	*Observing, Communicating, Comparing, Organizing* Sort illustrations of protozoans into appropriate groups.
Some protozoa move by means of hairlike structures (cilia) or by whipping tails (flagella).	*Observing, Communicating* Observe a paramecium under a microscope; illustrate and label its parts.
Algae are plant-like organisms that produce their own food and give off oxygen. (TA) Algae could be used in spacecraft oxygen-carbon dioxide recycling systems.	*Observing, Communicating, Comparing, Organizing,* Compare the conditions necessary for growth of protozoa, bacteria, fungi, and algae.
Given proper conditions of temperature, light, and nutrients, protists multiply rapidly. (TA) Protists are used in fermentation processes and waste disposal. Refrigeration preserves food by inhibiting the reproduction of protists.	*Observing, Communicating, Comparing, Organizing* Observe and describe graphically the growth of colonies of yeast, bacteria, or other protists (safety precautions).
Some bacteria need oxygen, and some do not.	*Observing, Communicating* Report on anaerobic bacteria found around oceanic hot springs.
Protists use oxygen and produce waste products.	
Protozoa and bacteria reproduce asexually by fission.	
Fungi and algae reproduce asexually by means of fission, budding, or spores and sexually by means of gametes. (TA) Fungi and algae can be cultured for use in food production and processing, medicine, and other areas.	*Observing, Communicating, Comparing* Examine the reproductive structures and processes of various fungi and algae under a microscope.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
Some protists are harmful to human beings by causing diseases, consuming useful materials, or giving off toxic waste products. (EC) Control of harmful protists involves both public policy and personal behavior.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Make a chart showing common protists that are either harmful or beneficial to humans and the specific impact of these organisms on the environment.
Some protists are helpful to human beings by consuming unwanted waste products or by giving off waste products that are useful. (TA) Protists are used in sewage treatment and fermentation processes.	
Some protists can be made to produce useful substances by artificial modification of their genetic material.[2]	*Observing, Communicating, Comparing, Organizing* Report on research regarding the development of immunization processes through genetic manipulation in protists.
Fungi obtain their food from plants, animals, or rotting plant and animal matter.[3]	
Algae carry on photosynthesis and are responsible for replenishing most of the atmospheric oxygen.[3]	*Observing, Communicating, Comparing, Organizing, Relating* Use references to report on the role of algae in maintaining the oxygen/carbon dioxide balance in nature.
Viruses are much smaller than the smallest protists. Viruses do not metabolize food or grow in the usual sense but reproduce within cells, using the cell material as nutrients.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use references and examine photomicrographs of viruses to identify characteristics and compare their reproductive cycles, sizes, and destructive effects with those of common protists.
Some viruses cause diseases in animals or plants by entering and killing large numbers of cells (e.g., some cancers).	
Viruses consist of DNA strands coated with protein molecules.	*Observing, Communicating, Comparing, Organizing, Relating* Use references and photomicrographs of viruses and protists to describe the structures and functions of their component parts.
Electron microscopes can be used to produce images of viruses and tiny organelles within cells.	*Observing, Communicating, Comparing, Organizing, Relating* Observe and compare photomicrographs of varying magnifications and relate them to actual sizes.

[1]This concept is also developed under "Biological Science—Human Beings" and "Biological Science—Ecosystems."

[2]This concept is also developed under "Biological Science—Cells, Genetics, and Evolution."

[3]These concepts are also developed under "Biological Science—Plants" and "Biological Science—Ecosystems."

Biological Science—Animals

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
Animals have characteristics by which they can be described and identified.	*Observing, Communicating, Comparing* Observe and describe a wide variety of animals, using live and preserved specimens, pictures, videotapes, and other sources.
There is great diversity among animals.	*Observing, Communicating, Comparing, Organizing* Observe and describe a variety of animals, and make a list of ways in which they differ. (Include worms, insects, snails, and other invertebrates, as well as fish, snakes, birds, mammals, and so forth.)
Animals can be classified according to various characteristics; e.g., size and body structures and where they live, what they eat, and so forth.	*Observing, Communicating, Comparing, Organizing* Observe pictures or specimens of animals, and sort them according to observable characteristics.
Animals move in different ways.	*Observing, Communicating, Comparing, Organizing* Group pictures of animals by how the animals travel (walk, run, crawl, hop, swim, or fly).
Animals live in a great variety of environments: oceans, fresh water, forests, deserts, tundra, and so forth.[1]	*Observing, Communicating, Comparing, Organizing* Look at pictures of animals in different environments or habitats. Develop a list of other animals that inhabit the same environment.
All animals need food, water, and air and a place to live.	*Observing, Communicating* Describe the four basic needs of all animals (food, water, air, and shelter). Demonstrate proper care of classroom animals and pets.
Animals reproduce their own kind.	*Observing, Communicating, Comparing* Match pictures of the adults and young of a variety of animals.
In some animals, including human beings and most other mammals, the young grow within the mother's body before they are born. In most other animals, the young develop from eggs laid by the mother.	*Observing, Communicating, Comparing* Observe, and describe the birth of an animal; e.g., guppies, cat, dog, rat, hamster, and the laying and hatching of eggs from a bird, amphibian, or reptile.

[1]These concepts are also developed under "Biological Science—Ecosystems."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Scientists classify animals into two major groups, those that have backbones; e.g., fish, snakes, frogs, birds, and mammals; and those that do not have backbones; e.g., worms, snails, insects, crabs, jellyfish, and starfish.	*Observing, Communicating, Comparing* Observe and describe examples of a variety of both major kinds of animals.
Animals have adaptations that enable them to obtain and conserve food, oxygen, and water; excrete waste products; move; protect themselves against predators, minimize effects of extreme temperatures; reproduce; and so forth.[1]	*Observing, Communicating, Comparing, Organizing, Relating* Compare the value of the most obvious adaptations of such animals as the camel, skunk, bee, crab, snail, and snake.
Animals depend on plants for food.	*Observing, Communicating, Comparing, Organizing* Develop a food chain for each of four different animals: an herbivore, a carnivore, an omnivore, and a scavenger.
Animals give off carbon dioxide, water, and other waste products.	*Observing, Communicating* List the source and nature of the waste products given off by animals.
Cold-blooded animals have body temperatures that vary somewhat with the surrounding temperatures.	*Observing, Communicating, Comparing, Organizing, Relating* Describe the behavior and movement of a grasshopper or a snake that has been kept in a cool place (50° to 60° Fahrenheit [10° to 16° C]) for one-half hour.
Warm-blooded animals have adaptations that enable them to control their body temperature within a narrow range.	*Observing, Communicating, Comparing, Organizing* Compare the physical characteristics of warm-blooded and cold-blooded animals. Compare the adaptations of birds and mammals that live in areas with very cold winters or very hot summers.
Sexual reproduction in animals occurs when a sperm cell fertilizes an egg cell and a new individual develops from the fertilized egg.	*Observing, Communicating* Observe and describe the reproductive cycle of an animal that reproduces sexually.
Some arthropods progress through a life cycle that involves several dissimilar forms (egg, larva, pupa, adult). (TA) Knowledge of arthropod life cycles is used in the commercial culture of lobsters and honeybees.	*Observing, Communicating, Comparing, Organizing* Make a book or a chart illustrating and describing the life cycle of a butterfly or mealworm.

[1]These concepts are also developed under "Biological Science—Ecosystems."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—6 (Continued)	
Invertebrates and cold-blooded vertebrates generally produce large numbers of fertilized eggs, but only a small fraction of the offspring survive to maturity. Birds and mammals produce fewer offspring, but a larger fraction survives.	*Observing, Communicating, Comparing, Organizing* Compare the number of eggs produced with the survival rate for a variety of common warm-blooded and cold-blooded animals.
Offspring of invertebrates and cold-blooded vertebrates generally receive no care from their parents once the eggs are deposited. They hatch and survive on their own with behaviors that seem to be largely instinctive.	
Offspring of birds and mammals receive parental care before and after they are hatched or born. Some of their behaviors appear to be learned.	*Observing, Communicating, Comparing, Organizing* Compare the parental care that adult birds and mammals give their offspring.
We can raise and keep some kinds of animals for use and enjoyment by providing the necessary conditions and care.	*Observing, Communicating, Comparing, Organizing* List the kinds of animals one can keep in a home or on a farm and the care needed to keep them healthy.
(EC) Proper care of pets and domestic animals and behaviors affecting the welfare of wildlife involve personal responsibility and social policy.	*Observing, Communicating, Comparing, Organizing* Demonstrate the proper care of classroom animals and pets.
6–9	
Animals obtain their energy from food in the form of plants, other animals, and protists.[1]	*Observing, Communicating, Comparing, Organizing, Relating* Classify animals into four basic groups: herbivores, carnivores, omnivores, and scavengers. Compare the specific physical characteristics common to each group; e.g., eye placement, teeth or beaks, claws, habitat.
Diet deficiencies can cause an animal's growth, activity, and reproduction to be impaired and, in extreme cases, cause the animal to die.	*Observing, Communicating, Comparing, Organizing* Give a detailed report on a deficiency disease or prepare a chart showing a variety of deficiency diseases, their causes, and the history of their discovery. Demonstrate proper care of classroom animals and pets.
Scientists' classifications of animals are based on similarities in body structures.	*Observing, Communicating, Comparing, Organizing, Relating* Observe and describe a variety of both vertebrate and invertebrate animals. Sort them using the major characteristics of standard invertebrate phyla and vertebrate orders.

[1]This concept is also developed under "Biological Science—Ecosystems."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued)	
In the early stages of development, embryos of different kinds of animals are very similar.	*Observing, Communicating, Comparing, Organizing* Examine illustrations showing the embryonic development and mature appearance of a variety of animals. Compare their similarities and contrast the differences at various stages.
Embryos of all animals that lay eggs get their food from within the egg until they hatch.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe and collect information on the reproduction cycles of egg-laying (e.g., fish) and placental (e.g., mice) classroom animals. Compare the sources of food for the developing embryos.
Embryos of most mammals obtain food and oxygen from the bloodstream of the mother through an organ called the placenta.	
Scientists' classifications of animals are based on a species' similarities in chemical compounds; e.g., enzymes and DNA, as well as anatomical similarities. The system of classification is closely related to modern theories of how animals have evolved.[2]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Develop a time line showing the sequence of appearance of major animal forms.
Animals break down protein from the plants and animals they eat to form their own proteins. (TA) Cattle and dairy farming and the leather-tanning industry are industries based on the conversion of plants to animal proteins.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Develop a food chain for a particular animal, including the quantitative relationships among the organism and energy sources involved.
(EC) Killing of animals for use by humans in such products as meats, leather, or trophies involves individual and social values.	

[2]This concept is also developed under "Biological Science—Cells, Genetics, and Evolution."

Biological Science—Human Beings

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
Human beings have characteristics by which they can be identified, described, and classified. (TA) Characteristics unique to an individual make possible identification by photographs and fingerprints.	*Observing, Communicating, Comparing, Organizing* Name the physical characteristics of humans that distinguish them from other animals.
Human beings get information about things by seeing, hearing, touching, tasting, and smelling.	*Observing, Communicating, Comparing, Organizing* Match the sensory organs of the human body with the sensory stimuli they perceive.
People need fresh air, good food, rest, and exercise to stay healthy.	*Observing, Communicating* Draw illustrations to show a person receiving each of the basic health needs.
People get sick or die when they inhale or swallow some things.[1]	*Observing, Communicating, Comparing, Organizing* List or draw illustrations of places in and around the home where dangerous drugs and hazardous chemicals may be located. Recognize symbols commonly used to denote poisons or hazardous materials.
Tools and machines can cause injuries if they are not used carefully.	*Observing, Communicating, Comparing, Organizing* Gather pictures of tools and machines, and display them with illustrations of the most likely way these devices may cause injuries.
Some kinds of sickness are caused by microorganisms.	*Observing, Communicating* Observe and describe how diseases are spread. Discuss social behaviors that prevent people from infecting others.
(TA) Immunization is necessary to protect against certain dangerous diseases.	
Doctors and nurses help to find out what is wrong with people when they are sick or injured, and they help them get well.	*Observing, Communicating* Describe the tools and procedures in examining a patient.
The body usually heals itself when it becomes sick or injured.	*Observing, Communicating, Comparing, Organizing* Describe the differences between the healing or recovery time for cuts or bruises, broken bones, colds, and common diseases.

See the *Health Instruction Framework for California Public Schools.* Sacramento: California State Department of Education, 1978.

[1]Related concepts are developed under "Physical Science—Matter."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

3–6

Human beings are mammals.

Observing, Communicating, Comparing, Organizing

Compare the physical characteristics of humans with the corresponding characteristics of other mammals.

The organs of the human body form systems that carry on essential bodily functions: skeletal, muscular, respiratory, digestive, circulatory, excretory, endocrine, nervous, and reproductive.

Observing, Communicating, Comparing, Organizing, Relating

Observe and record the breathing rates of five classmates before, immediately after, and two minutes after vigorous exercise, and then prepare graphs of and describe the results.

Observing, Communicating, Comparing, Organizing, Relating

Plan, conduct, and report the results of an investigation to determine the sensitivity to touch of various parts of the human hand and arm.

Human beings grow and develop in similar ways but at various rates. Individuals of the same age vary in their stages of growth and development.

Observing, Communicating, Comparing, Organizing, Relating

Measure, record, graph, and describe the heights of classmates in studying the variations in developmental rates.

Adolescence is a period of rapid, uneven growth and development of human beings, during which sexual maturation occurs.[1]

Observing, Communicating, Comparing, Organizing

Sequence and compare the physical changes that take place in human males and human females during adolescence.

See the *Health Instruction Framework for California Public Schools*. Sacramento: California State Department of Education, 1978.

[1]Instruction in human reproduction and sexuality is subject to *Education Code* Section 51550. Special care should be taken that these concepts are introduced at the appropriate level according to local district policy. See page 108.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—6 (Continued)	
Eggs that are produced and mature in the ovaries of the human female are released at the rate of about one per month as a part of a process called the menstrual cycle.[1]	*Observing, Communicating, Comparing, Organizing* List in sequence the occurrences during the normal menstrual cycle.
Sperm are produced by the hundreds of millions in the testicles of human males.[1]	*Observing, Communicating, Comparing, Organizing* Trace on a diagram the movement of the human sperm from production to release through the penis.
Sexual intercourse is a behavior in which sperm are released through the penis of the male into the vagina of the female.[1]	*Observing, Communicating, Comparing* Compare pictures or models of male and female reproductive organs, and describe the function of each.
Conception occurs when a sperm cell enters and fertilizes the egg cell. The implantation and development of the embryo take place in the uterus. (EC) Responsibility with respect to sexual behavior is both an individual and a social concern.[1]	*Observing, Communicating, Comparing, Organizing* Sequence a series of pictures of models showing fertilization and the early stages of embryonic development.
Conditions for good health of the human body include exercise, adequate rest, protection from extreme temperatures, avoidance of toxic substances, avoidance of severe physical injury, avoidance of disease, and the absence of genetic defects.[2]	*Observing, Communicating, Comparing, Organizing* Conduct library research and prepare a chart listing in detail conditions for good health.
(EC) Most of the conditions for good health involve responsible behavior on the part of individuals and of groups.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Prepare a report on the need for individuals and groups to assume responsibility for their health as well as the health of others.

[1]Instruction in human reproduction and sexuality is subject to *Education Code* Section 51550. Special care should be taken that these concepts are introduced at the appropriate level according to local district policy. See page 108.

[2]Related concepts are developed under "Physical Science—Matter," each energy section under "Physical Science," and "Earth Science—Geology and Natural Resources."

6–9

Human beings belong to an order of mammals called primates.	*Observing, Communicating, Comparing, Organizing* Describe the characteristics of primates, and list those characteristics unique to humans.
Very thin, moist membranes in the lungs permit oxygen molecules to diffuse from air into the blood and carbon dioxide molecules to diffuse from the blood into the air.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Determine that carbon dioxide is released from the human body by conducting an experiment that compares the effects of exhaled air and atmospheric air on limewater.

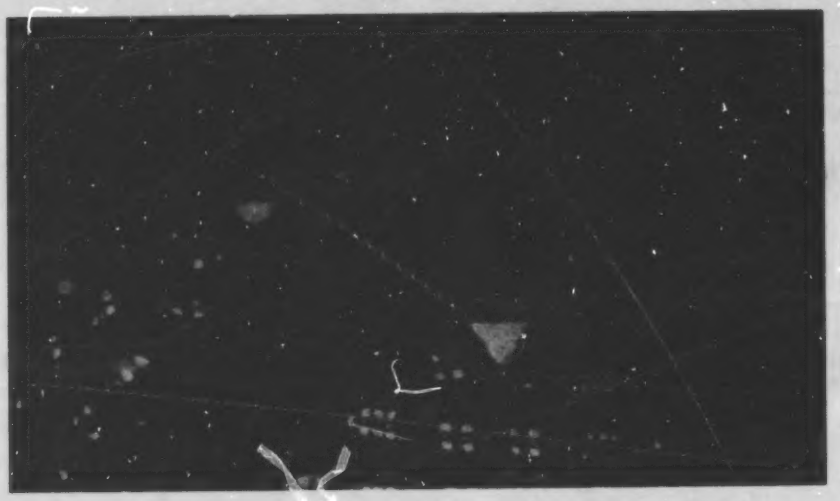
Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9 (Continued)	
Hemoglobin, found in red blood cells, is the protein that carries oxygen from the lungs to the cells and some carbon dioxide from the cells back to the lungs.	*Observing, Communicating, Comparing, Organizing* Examine a sample of human blood under a microscope, and prepare a chart detailing the major functions of each component.
Human infants and children take longer to mature and thus are dependent on parental care longer than is the case with other animals.	*Observing, Communicating, Comparing, Organizing* Compare the dependence period of human offspring with that of a variety of other mammals.
(EC) Responsible attitudes and behaviors with respect to sexual behavior, child care, and other family relationships are important to individuals and society.	
Unlike other animals, human beings are capable of controlling their own reproductive rate through the control of their behavior and the use of a variety of techniques to prevent conception.[1]	*Observing, Communicating, Comparing, Organizing, Relating* Use library resources to prepare a list of reasons for humans to control their reproductive rate.
(EC) Responsible behavior is especially important where permanent damage to an individual may result, where long-term effects are unknown, and where damage or disease may be transmitted to others.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Give a report regarding nutritional, drug-related, radiation, and communicable disease effects on humans at all stages of development, growth, and maturation.

[1]Instruction in human reproduction and sexuality is subject to *Education Code* Section 51550. Special care should be taken that these concepts are introduced at the appropriate level according to local district policy. See page 108.

9–12

Fossil evidence indicates that tool-using primates with human characteristics appeared on earth at least 3.5 million years ago.	
Humans differ from other mammals in the size and complexity of their central nervous system. This difference gives rise to a much greater ability of humans to learn, respond in a variety of ways to stimuli, store and process information, communicate, and manipulate the environment.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Explain how humans have been able to establish a dominant position in the total environment. Compare the central nervous system of humans with other primates and cetaceans.
Nerve impulses are waves of electrochemical reactions that travel very rapidly. Many drugs affect the nervous system, causing changes in perception, control of bodily functions, and behavior.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Investigate the effects of various drugs on microorganisms (safety precautions).

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9--12 (Continued)	
(TA) In electroencephalography electrical impulses produced in the brain are used to study brain function and to diagnose brain damage.	
(EC) Attitudes and behaviors conducive to safety and good health for oneself and others are an individual and social concern.	
The human organism has many automatic mechanisms by which it counteracts or minimizes the effects of substances or stressful conditions that upset its functions. This tendency for the human body to restore itself to a normal state is called homeostasis. Some of the important mechanisms include temperature control, immune reactions, coughing and sneezing, clotting of blood, healing of fractured bones and other damaged tissue, excretion of toxic substances or excess nutrients, and hormonal control. All of these control mechanisms have limits.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Investigate and demonstrate a variety of automatic responses of the body, including knee reflexes, breathing and heart rate, responses to exercise and stress, temperature control, and blood clotting (safety precautions).
Perception is the way stimuli are received and interpreted. Perception is affected by many factors. The same stimulus may be perceived differently by different individuals or by the same individual under varying conditions.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Graph the reaction times of classmates on a given test, and predict the upper and lower limit of reaction time for additional students.
Enzymes and other chemical secretions in the digestive system convert large molecules into simpler ones (e.g., starch into sugars, or proteins into amino acids) and break fats into tiny particles that can be carried to the cells by the circulatory system.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Test the breakdown of starches and proteins by the appropriate enzymes.



Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9—12 (Continued)	
The control of disease and the use of technology to increase food production have resulted in rapid human population growth, especially during the past 100 years.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Develop and compare graphs and other information regarding population growth, deaths from common diseases, and food production from 1800 to the present.
(EC) Optimum population size and factors that tend to limit or increase the rate of population growth involve individual and societal decisions and behavior.	
Human beings' ability to perceive the consequences of unchecked population growth and their ability to control their reproductive rate give them the possibility and responsibility to control their population without the suffering that accompanies the disease, starvation, and other forms of population limitation found in nature.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Compare projections of human population growth with projections of the availability of food and natural resources. Use the information to propose alternative courses of action.
Medical care usually involves one or another kind of assistance to the body's natural mechanisms for homeostasis. (TA) Forms of assistance include advice about behaviors that will improve health; immobilization and protection of tissues to allow healing; surgical removal of diseased tissues or organs; correction of defects; surgical transplanting of healthy tissues or organs to replace diseased ones; administration of chemical antidotes or antibiotics to neutralize toxins and help the body fight pathogens; administration of hormones or metabolic intermediates that are not produced in adequate quantities in the body (e.g., insulin for diabetics); suppression of immune reactions that have gone awry; use of prosthetic devices to replace or supplement organs that are missing or not functioning adequately (e.g., crutches, eyeglasses, dental plates, artificial limbs, heart valves, and so forth).	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Prepare a time line for the development of health-related information and technology, including projections for the future.
(EC) Access to medical care and the prolonging of human life are ethical concerns involving individuals, the medical profession, and society.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Use library references to prepare a personal position statement on socialized medicine.

See the *Health Instruction Framework for California Public Schools*. Sacramento: California State Department of Education, 1978.

Biological Science—Ecosystems

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
Living things need special kinds of food and a special place to live.	*Observing, Communicating, Comparing, Organizing* Observe and report on where different kinds of plants and animals live.
Living things get things they need from each other and from the environment.	
The same kinds of living things often live together in groups.	*Observing, Communicating, Comparing, Organizing* Prepare a list of sets that describe animals living in groups; e.g., herd, pride, flock, covey.
Usually, several kinds of living things live with or near each other.	*Observing, Communicating, Comparing, Organizing* Observe and describe a variety of organisms living together in communities.
All animals eat plants and/or other animals.	*Observing, Communicating, Comparing, Organizing* Match pictures of different foods with pictures of the plants or animals from which these foods come.
Living things change from day to day, season to season, year to year.	*Observing, Communicating, Comparing, Organizing* Observe a flower changing into seeds. Observe tadpoles changing into frogs.

See the *California Environmental Education Guide*, Volume 3. Hayward, Calif: Office of the Alameda County Superintendent of Schools, 1981.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
All the individuals of one species that live in a limited area are called a population. Populations can be counted, and their size can be estimated using sampling techniques.	*Observing, Communicating, Comparing, Organizing, Relating* Select three topsoil samples, count the insects, group them into similar kinds, and estimate the number of each in a square meter plot.
Population sizes often vary in cycles related to seasons, reproductive patterns, and so forth. Population sizes are subject to limitations imposed by space, food supply, predators, and the destruction of habitats by natural disasters or human activity. Populations sometimes die out. When all the populations of a species die out, it becomes extinct. **(EC)** The effect on other populations needs to be considered along with other costs and benefits when human activities that affect the environment are evaluated.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Compare an insect species population at different seasons of the year, and infer the reasons for the variations noted.
Each species needs a particular physical environment.	*Observing, Communicating, Comparing* Compare the aspects of the physical environment of different ecosystems; e.g., temperature, moisture, and light.
All living things that share a particular environment are called a community. An ecosystem consists of a community of living things interacting with each other and with the physical environment. Major types of ecosystems include aquatic (pond, creek, ocean, or estuary) and terrestrial (grassland, chaparral, forest, or desert).	*Observing, Communicating, Comparing, Organizing* Prepare and label a chart illustrating the living things in a particular ecosystem.
Most ecosystems derive their energy from the sun through photosynthesis in green plants (producers). Animals and some plants (consumers) derive their energy from plants and/or other animals. Decomposers (usually microorganisms like bacteria and fungi) get their energy from dead plant and animal matter and animal waste products, breaking them down into simple substances such as carbon dioxide, methane, ammonia, water, and mineral salts.	*Observing, Communicating, Comparing, Organizing, Relating* Prepare, maintain, and record the interactions (both biological and chemical) in a balanced aquarium. Adjust the balance as necessary over time.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—6 (Continued)	
Food chains and food webs indicate the eating patterns of the members of an ecosystem. Predators are animals (and a few plants) that kill and eat other animals (prey). Scavengers are animals that eat dead plant and animal tissue. Parasites are animals or plants that feed off other animals or plants called hosts. (TA) Knowledge of food chains and webs is used in biological control of pests.	*Observing, Communicating, Comparing, Organizing, Relating* Illustrate a food web of an ecosystem, including at least one of each of the following: producers, primary consumers, predators, scavengers, parasites, and decomposers.
6–9	
Two kinds of organisms sometimes have a permanent relationship called symbiosis that benefits one or both. In some such relationships both benefit (mutualism); in others one benefits and the other is unaffected (commensalism), and in still others one benefits and one is harmed (parasitism).	*Observing, Communicating, Comparing, Organizing* Observe, describe, and compare examples of parasitism, commensalism, and mutualism. Compare symbiotic relationships with human social relationships.
Some animal species live cooperatively in permanent or temporary groups. In some animal species, individuals in a population perform specialized functions; e.g., as in colonies of ants, troops of primates, and human societies.	*Observing, Communicating, Comparing, Organizing* Research animal grouping patterns and compare the role of individuals in groups of humans and in social insects such as the bee or ant.
Some animal species compete for territory. In some species individuals compete for rank, including the right to reproduce.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe in aquaria, animal cages, or films the territoriality and selective breeding patterns among and within animal species. Speculate regarding the adaptive advantages of such behavior.
Populations may stabilize over a period of time in a balanced ecosystem.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe a variety of ecosystems then hypothesize regarding the characteristics of a balanced ecosystem.

See the *California Environmental Education Guide*, Volume 3. Hayward, Calif.: Office of the Alameda County Superintendent of Schools, 1981.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued)	
Long-term population changes occur as climates change.	
Succession is a process in which some ecosystems change over time. As changes occur in physical features of the system, new species move in, population sizes change, and so forth.	*Observing, Communicating, Comparing, Organizing* Use library reference materials to illustrate and describe the succession of a pond or lake into a wooded area. Observe and describe examples of succession; e.g., intrusion of weeds into a parking lot.
Food chains and food webs indicate the flow of energy that maintains an ecosystem.	*Observing, Communicating, Comparing, Organizing* Use references to develop a food pyramid for a carnivore and an omnivore, relating the ultimate energy source to the sun.

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Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
Matter needed to sustain life in an ecosystem is cycled and reused. Some of the major cycles are the carbon cycle, nitrogen cycle, water cycle, and various mineral cycles.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use references to prepare an illustration showing oxygen, carbon, nitrogen, and water cycles and their relationships to a given animal.
Because of the intricate relationships that exist among the living things and because of the abiotic features of an ecosystem, a change to one part of the system may have far-reaching consequences to the system that are difficult to predict or control.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Predict the results of introducing a living organism that preys on one component of an ecosystem and has no predators there.
The human species poses special problems for ecosystems because of the recent rapid increase in human population; depletion of resources; widespread use of technology to alter the environment; widespread manipulation of populations of other species; and pollution of air, water, and land.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Prepare an essay on the topic, "The Impact of Humans on the Environment of the North American Continent During the Last 500 Years." Predict the impact of human behaviors on particular local environments; e.g., smog, landfill, logging, and water depletion.
(EC) Land use, pollution, energy use, and application of technology all involve ethical considerations for individuals and society.[1]	
(TA) Understanding of life cycles, predator-prey relationships, metabolism of organisms, and so forth make possible the control or eradication of populations of destructive organisms. Such activity always has some effects on the rest of the ecosystem.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Prepare to debate the topic, "Pests Can Be Controlled Without Damage to the Ecosystem."

See the *California Environmental Education Guide*, Volume 4. Hayward, Calif: Office of the Alameda County Superintendent of Schools, 1981.

[1]Closely related concepts are developed under "Earth Science—Geology and Natural Resources," "Earth Science—Meteorology," and under "Physical Science—Energy: Sources and Transformations."

Earth Science—Astronomy

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
Patterns of stars in the sky are called constellations. Each season has a different set of constellations that can be seen during the evening.	*Observing, Communicating, Comparing* Use a star map to locate major constellations. Make a model of the northern sky. Observe the evening sky at different times of the year.
The sun appears to move across the sky during the day, rising in the east and setting in the west.	*Observing, Communicating* Observe and describe the apparent motion of the sun during a day and the changes in shadows cast by the sun (safety precautions).
The moon appears to move across the sky, rising in the east and setting in the west; its shape appears to change during the course of a month.	*Observing, Communicating, Comparing* Observe that the moon seems to change position when observed at the same time on subsequent days. Draw pictures of the moon's changing shape during the course of a month.
Daylight periods are longer in the summer months and shorter in the winter.	*Observing, Communicating, Comparing* Compare the length of daylight periods at different seasons.
3–6	
Day and night and the apparent daily motion of the sun, moon, and stars across the sky result from the earth's rotating on its axis approximately once each 24 hours.	*Observing, Communicating, Comparing, Organizing* Observe and describe the apparent motion of the sun, moon, and stars across the sky (safety precautions). Keep records over time that will indicate the apparent motion of the sun, moon, and stars. Make and use a sundial.
The earth completes a nearly circular orbit around the sun in 365 ¼ days; different stars appear at different times of the year because different parts of the sky are exposed to the dark side of the earth. (TA) The prediction of seasons, floods, and so forth in ancient times employed these phenomena.	*Observing, Communicating, Comparing, Organizing, Relating* Use a light source and a ball to illustrate the rotation of the earth on its axis and the orbital motion about the sun.
The sun is a star—a huge, massive sphere of very hot matter approximately 150 million km (93 million miles) away; the moon is a cold, rocky, dusty sphere about 385,000 km (240,000 miles) away.	*Observing, Communicating, Comparing* Gather information about the sun and moon from a variety of sources.
Moonlight is reflected sunlight. The same side of the moon always faces the earth. As the moon and earth change relative positions in their orbits, we see the part of that side that is sunlit.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use a model of the earth, sun, and moon system to explain the phases of the moon.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—6 (Continued)	
Eclipses occur when the earth, sun, and moon come into alignment so that the earth's shadow falls on the moon (lunar eclipse) or the moon's shadow falls on the earth (solar eclipse).	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use a model of the earth, sun, and moon system to explain eclipses.
Planets are objects that appear to the naked eye like stars but reflect sunlight and do not stay in the same place in the sky relative to the stars; stars are objects like the sun, but they are much farther away.	*Observing, Communicating, Comparing, Organizing, Relating* Observe and describe stars and planets, using a telescope or binoculars. Observe the night sky, and describe how some objects (planets) change position relative to the stars over a period of weeks.
The earth is one of nine known planets that orbit the sun; most planets have one or more satellites or moons. The four inner planets are rocky; the next four are balls of gas; and the outermost planet, Pluto, is icy.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Construct a model of the solar system, and use it to describe the motions of the planets and their changes in position relative to the stars.
Asteroids are small planet-like bodies, ranging in size from a kilometer or less to almost a thousand kilometers. They orbit the sun mainly between the orbits of Mars and Jupiter. Over 3,000 asteroids are presently known. Meteoroids are chunks of matter revolving about the sun; most are probably fragments of comets or asteroids, ranging in size from tiny specks to many tons. Those which enter the earth's atmosphere are called meteors; most burn up before they strike the earth. Fragments that reach the earth's surface are called meteorites. Comets are large balls of frozen gas and dust that are pulled through the solar system by the sun's gravity. Some, such as Halley's Comet, are in large orbits and reappear regularly. Others fall into the sun or move in paths that do not return to the sun.	*Observing, Communicating, Comparing, Organizing* Use a variety of sources to obtain information about asteroids, meteors, and comets.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

6–9

Light from stars provides information about their temperature, size, age, composition, and distance. Stars can be classified according to those characteristics.

Distances to stars are so great that direct measurement is not possible. Distances are commonly expressed in light years: One light year is the distance light travels in one year, about 9.5 x 10^{12} (9.5 trillion) kilometers (6 trillion miles).

The earth's axis is tilted (23½°) from being perpendicular to the plane of its orbit about the sun. Summer occurs in the northern or southern hemisphere when this part of the earth is tilted toward the sun, resulting in longer daylight hours and in a more nearly perpendicular incidence of the sun's rays. Winter occurs when the hemisphere is tilted away from the sun, resulting in shorter daylight hours and in a lower angle of incidence of the sun's rays.[1]

The sun is part of a galaxy called the Milky Way, made up of hundreds of billions of stars. Telescopes make it possible to see that there are millions of galaxies.

[1]This concept is also developed under "Earth Science—Meteorology."

Observing, Communicating, Comparing, Organizing, Relating

Construct and use a simple spectroscope to observe and describe bright-line spectra of various elements.

Observing, Communicating, Comparing, Organizing, Relating, Inferring

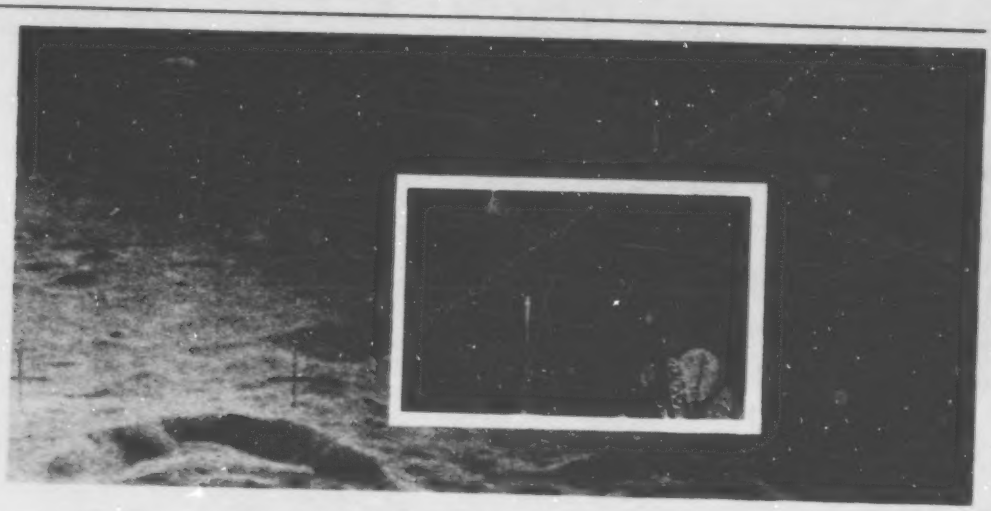
Construct or describe a scale model to represent the distances between the planets and the sun and the sun's nearest star neighbor.

Calculate the distance to objects by triangulation.

Observing, Communicating, Comparing, Organizing

Observe and compare the intensity of the illumination of a surface held at various angles to a light source.

Observe and compare the intensity of the heating of a surface held at various angles to a heat source.



Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
The sun and other stars release energy from thermonuclear (fusion) reactions.[1]	
Stars are believed to form as large amounts of gas and dust in space come together by gravitation until the pressure and temperature are so high that nuclear fusion occurs.	*Observing, Communicating, Comparing, Organizing* Gather information from a variety of sources on the evolution of stars and galaxies and the thermonuclear reactions that take place in stars.
A theory of how galaxies and stars evolve enables us to estimate their age and the age of the universe.	
There is no direct evidence that life exists elsewhere than on earth. However, the large number of stars in the universe makes it probable that many stars have planets capable of supporting life.	
Expeditions to the moon and space probes to other planets have provided information useful in estimating how these bodies were formed and how they have changed.	
(TA) Knowledge of the regular motions of the earth, sun, and moon relative to each other enables one to make accurate predictions of the times and heights of tides and the times and places at which eclipses can be observed.[2]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Use a tide table to determine the times and magnitudes of high and low tides at a given location. Relate tidal ranges to phases of the moon.
There is no evidence of life on other planets in our solar system. What we have learned about them makes it very unlikely that they could support life.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Gather information from a number of sources on conditions necessary for life to exist. Identify specific conditions on planets that make existence of life on them unlikely.
Spacecraft employing a variety of remote sensing devices have been sent to the surface of Venus and Mars and to the vicinities of Mercury, Jupiter, and Saturn. Instruments on board have transmitted information about these planets. Spacecraft flybys of Uranus, Neptune, and several comets (including Halley's) are anticipated in the next few years. Remote sensing techniques are used with earth satellites and aircraft to provide information about the earth's surface and atmosphere.	

[1]This concept is more fully developed under "Physical Science—Matter."

[2]This concept is also developed under "Earth Science—Oceanography."

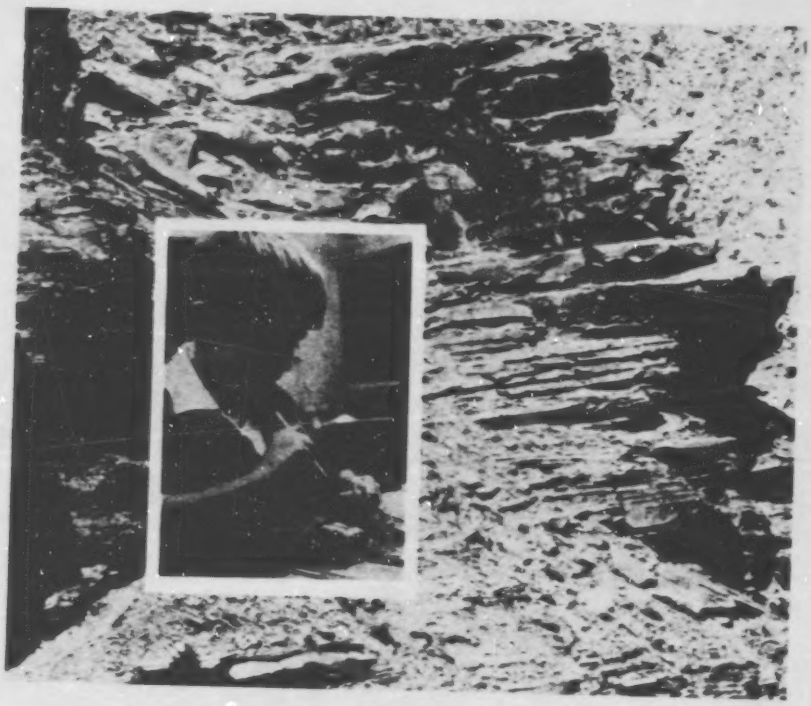
Earth Science—Geology and Natural Resources

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
Rocks have properties by which they can be described.	*Observing, Communicating, Comparing, Organizing* Observe, describe, and sort rocks by such properties (one at a time) as color, texture, size, and weight.
Soils have properties by which they can be described.	
Soils provide water and nutrients to plants.[1]	
The earth's surface consists of a variety of features, such as mountains, valleys, plains, deserts, rivers, lakes, oceans, and ice caps.	*Observing, Communicating, Comparing* Observe and describe the geologic features in pictures and models and in the nearby environment.
Humans depend on many resources of their surroundings for the necessities of life.[2]	*Observing, Communicating* Observe and describe ways in which humans use land, water, air, and mineral resources.

See the *California Environmental Education Guide*, Volume I. Hayward, Calif: Office of the Alameda County Superintendent of Schools, 1981.

[1]This concept area is more fully developed under "Biological Science—Plants."

[2]This concept area is also developed under "Biological Science—Ecosystems."



Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Rocks are classified according to characteristics peculiar to the process by which they are formed: igneous, sedimentary, and metamorphic.	*Observing, Communicating, Comparing, Organizing* Observe, describe, and classify rock samples as sedimentary, igneous, or metamorphic.
Rocks are made up of minerals in a great variety of combinations.	*Observing, Communicating, Comparing* Compare a variety of rocks on the basis of their mineral composition.
Minerals have specific properties, such as color, hardness, luster, and crystal shape. (TA) The properties of some minerals make them useful as jewelry or abrasives or as building materials.	*Observing, Communicating, Comparing* Use appropriate instruments to observe, describe, and compare the physical properties of minerals (safety precautions).
Rocks are broken into smaller pieces by physical, chemical, and biological weathering processes. Major agents of erosion are running water, glaciers, and wind.	*Observing, Communicating, Comparing, Organizing, Relating* Observe and identify products of weathering; formulate hypotheses about the processes that formed them.
Soils are formed from particles of rock mixed with dead plant and animal matter.[1]	*Observing, Communicating, Comparing* Use a hand lens to observe, describe, and compare soil samples.
Formation of soils is affected by climate, topography, living things, rock composition, and time.[1]	
Volcanoes occur where hot gases and melted rock (magma) from deep in the earth's crust are forced under pressure through openings in the crust.	*Observing, Communicating* Observe and identify geologic formations resulting from volcanic activity. Use a model or diagram of a volcano to describe volcanic processes. Identify locations in California where volcanic activity has occurred.

[1]This concept is also developed under "Biological Science—Plants."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6 (Continued)	
Earthquakes occur when blocks of the earth's crust under strain suddenly slip past each other along fault lines.	*Observing, Communicating* Use a model of a portion of the earth's crust to demonstrate what causes an earthquake. Identify areas in California where major earthquakes have occurred.
Earthquakes can injure or kill people as well as damage property.	*Observing, Communicating* Describe how to protect yourself in an earthquake.
Major natural resources needed by humans include air, water, soil, minerals, plants, animals, sources of energy, and areas of natural beauty. Natural resources are in limited supply.[2] **(EC)** Conservation of resources is an ethical concern of individuals and societies.[2]	*Observing, Communicating* Identify natural resources unique to or especially abundant in California.

See the *California Environmental Education Guide*, Volume 2. Hayward, Calif. Office of the Alameda County Superintendent of Schools, 1981.

NOTE: Concepts in paleontology have been included under "Biological Science—Cells, Genetics, and Evolution."

[2]This concept is also developed under "Biological Science—Ecosystems."

6–9

Geologic processes occur over millions of years as rocks rise from beneath the earth's crust, are weathered into small particles which are deposited as sediment, are buried and metamorphosed, and are eventually returned to the earth's interior. The histories of landscapes can be inferred from these processes.[1] Iron particles embedded in rocks reveal that the earth's magnetic field has fluctuated over geologic time. Characteristics of mineral crystals are consequences of the way their atoms are bonded together in geometric patterns.[2]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Relate properties of various crystals to models of their lattices.

[1]This concept is also developed under "Earth Science—Oceanography."

[2]This concept is also developed under "Physical Science—Matter."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued)	
Earthquakes and volcanoes release large amounts of energy and make major changes to land forms in a short time.	*Observing, Communicating, Comparing, Organizing* Observe and describe land formations (preferably local) resulting from past earthquakes or volcanic activity. Describe the destructive effects of earthquakes and volcanism in California's recent history.
Earthquakes produce wave motions that can be measured to determine location and magnitude.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Demonstrate earthquake wave motions.
The model of plate tectonics explains many features and phenomena found on earth, such as the shapes and locations of the continents, mountain ranges, volcanoes, ocean trenches, and earthquake belts.	
The ages of geologic formations, of events in the distant past, and of the earth itself can be estimated by observing processes, such as radioactive decay, sedimentation, erosion, and so forth, and by assuming that these processes occurred in the past much as they occur today. Several such lines of evidence indicate the age of the earth to be 4 to 5 billion years.[3]	
The geologic time scale is used to place geologic events in a time sequence.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use information gathered from a variety of sources to construct a geologic time line.
Energy is required to convert matter from a less useful into a more useful form for human needs; e.g., ore into metal, sea water into fresh water, and carbon dioxide and water into plant tissue. Renewable resources are those for which this conversion comes about naturally in relative short cycles, using the sun's energy; e.g., carbon, nitrogen, and water cycles. Nonrenewable resources are produced in much longer cycles (e.g., rock or fossil fuel cycles) and thus tend to be consumed faster than they are replenished.[4]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Identify major renewable resources, citing the energy conversions involved in renewing them. Identify major nonrenewable resources, citing the energy conversions involved in obtaining, refining, distributing, and using them.
(EC) Conservation of resources, and management of renewable resources are ethical concerns involving individual behavior and public policy.[4]	

[3]Concepts in paleontology have been included under "Biological Science—Cells, Genetics, and Evolution."

[4]Closely related concepts are developed under "Biological Science—Ecosystems" and "Physical Science—Energy: Sources and Transformations."

See the *California Environmental Education Guide*, Volume 3. Hayward, Calif.: Office of the Alameda County Superintendent of Schools, 1981.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
The atmosphere, hydrosphere, lithosphere, and biosphere act as a dynamic system.	
Magnetic anomalies caused by normally and reversely magnetized rocks in ocean sediments reveal that ocean floors have been slowly spreading and changing shape over millions of years.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Describe evidence for magnetic reversals and explain how sea floor spreading is inferred from the evidence.
Earthquakes, landslides, volcanic activity, floods, coastal storms, and ground subsidence in populated areas can injure or kill people as well as damage property. **(TA)** Methods of predicting these events are being investigated. **(EC)** Minimizing injury and loss of life in earthquake-prone populated areas involves planning, public policy, and individual preparedness.	*Observing, Communicating, Comparing, Organizing* Locate and report on information about the effects of major earthquakes on populated areas. Locate and report on information about attempts by geologists to predict earthquakes and volcanic activity.
(TA, EC) Care in the design, construction, and location of structures in earthquake-prone areas can minimize damage, injury, and loss of life in major earthquakes.	*Observing, Communicating, Comparing, Organizing* Locate and report on information about the design and construction of structures to withstand the effects of earthquakes. *Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Construct and test models of structures incorporating earthquake-resistant features.

[1]The concept of magnetism is developed under "Physical Science—Energy: Electricity, and Magnetism."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9—12 (Continued)	
	Observing, Communicating, Comparing, Organizing Locate and report on information about state and local codes relating to the location, design, and construction of structures with respect to earthquake hazards.
	Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying Identify and describe ways in which the learner's own dwelling could be made safer and less vulnerable to earthquake damage.
Nonrenewable resources can be conserved through careful use, recycling, and application of energy. If the energy applied comes from a nonrenewable source such as fossil fuels, then the effect is to trade one nonrenewable resource for another. If the energy is taken from a renewable resource such as the sun, then a net gain in resources is made.[2]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Compare the energy and natural resource consumption involved in alternative solutions to the same problems; e.g., glass, plastic, aluminum, or steel containers for liquids; various forms of transportation, recreation, protective coatings, clothing, food, and so forth. Evaluate the alternatives.
(EC) All decisions involving the use of natural resources and energy sources have an ethical dimension and, thus, are of concern to both individuals and societies.	
	Observing, Communicating, Comparing, Organizing, Relating, Inferring Compare the energy required to collect and recycle a material such as aluminum, glass, or iron with the energy required to produce this product from raw materials.
Space travel by human beings requires a self-sustaining (closed) system such as the earth in which all of the resources necessary to maintain life are present and there is sufficient incoming energy to renew them.	*Observing, Communicating, Comparing, Organizing* Locate and report on information on how the resource and energy problems have been solved in manned space exploration so far; e.g., Apollo missions, spacelab, or space shuttle.
	Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying Draw a plan or construct a model of a spacecraft designed to support human life over extended periods of time.

See the *California Environmental Education Guide*, Volume 4. Hayward, Calif.: Office of the Alameda County Superintendent of Schools, 1981.

[2]Closely related concepts are developed under "Biological Science—Ecosystems" and "Physical Science—Energy: Sources and Transformations."

Earth Science—Meteorology

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

K–3

Air is all around us.

Observing, Communicating

Observe and describe some properties of air. Determine that air occupies space; e.g., by handling a plastic bag of trapped air.

The sun warms the earth, which warms the air.[1]

Observing

Feel heat produced by the sun.

Observing, Communicating, Comparing, Organizing

Compare air temperatures produced by the sun (a sunny day versus a cloudy day; a summer day versus a winter day).

Wind is moving air. Wind direction can be measured.[1]

Observing, Communicating, Comparing, Organizing

Make and use a wind direction indicator (wind vane).

Water evaporates and condenses, freezes and melts.

Observing, Communicating

Observe and describe examples of evaporation and condensation, freezing and melting of water; e.g., fishbowl, terrarium, window pane, or ice cubes.

Clouds have characteristics by which they can be described and classified.

Rain and snow come from some kinds of clouds.

Observing, Communicating, Comparing

Observe, describe, and identify cloud types.

Weather phenomena can be described.

Observing, Communicating, Comparing, Organizing

Keep a simple weather chart.

Weather affects plants and animals.

[1]This concept is also developed under "Earth Science—Oceanography" and "Physical Science—Matter."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Air pressure is greatest at the earth's surface and decreases regularly with altitude.	*Observing, Communicating, Comparing, Organizing, Relating* Make and use a barometer to measure air pressure. Describe how a barometer operates.
Air heated by contact with the sun-warmed earth becomes lighter and is pushed upward by cooler air.	*Observing, Communicating, Comparing, Organizing, Relating* Make and use instruments to measure air movement (anemometer, wind vane, or nephoscope), and describe their operation. Detect warm and cool air currents. Measure air temperature.
Winds result from differences in air pressure, which are caused mainly by uneven heating of air masses. (TA) Wind is used as a source of energy for sailing vessels and wind-powered generators.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Measure and compare the surface temperatures of a pond and various land surfaces on a sunny day. Explain how differences could cause air currents.
Surface features affect the wind direction.	*Observing, Communicating, Comparing, Organizing, Relating* Identify local surface features that are likely to affect the wind direction.
Wind speed and direction can be measured.[1]	*Observing, Communicating, Comparing* Use instruments to measure wind direction and speed.
Heat from the sun changes water from solid into liquid and liquid into gas.[2]	*Observing, Communicating, Comparing* Observe, compare, and describe rates of melting and evaporation of water from containers of water placed in sunlight and in shade.
Humidity is a measure of the amount of water vapor in the air.	*Observing, Communicating, Comparing, Organizing, Relating* Make and use a humidity indicator (hygrometer), and explain how it works.
Dew and frost occur when water vapor condenses as air touches cold surfaces.[3]	*Observing, Communicating, Comparing, Organizing* Observe and describe the circumstances under which dew and frost form. *Observing, Communicating, Comparing, Organizing, Relating* Create conditions to demonstrate condensation of water as a liquid and as a solid.

[1]This concept is also developed under "Physical Science—Mechanics."

[2]This concept is also developed under "Physical Science—Matter" and "Earth Science—Oceanography."

[3]This concept of phase changes is also developed under "Physical Science—Matter."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—6 (Continued)	
Clouds and fog form when moist air is chilled and water vapor condenses.[3]	*Observing, Communicating* **Observe** and describe conditions under which clouds and fog form.
Air with water vapor cools as it rises. When water vapor cools below a certain temperature (dew point), it condenses into clouds of tiny droplets or into ice crystals.[3]	*Observing, Communicating* **Observe** and describe what occurs when clouds form.
When enough water accumulates in clouds, rain or snow falls.	*Observing, Communicating* **Observe** and describe cloud conditions when rain or snow is falling. **Observe** and describe snowflakes. *Observing, Communicating, Comparing, Organizing, Relating* **Construct** a rain gauge, and explain its operation.

[3]This concept of phase changes is also developed under "Physical Science—Matter."

6–9

Stormy weather is usually associated with low atmospheric pressure; fair weather, with high pressure. (TA) Weather predictions are based on this concept.	*Observing, Communicating, Comparing, Organizing, Relating* **Use** a set of meteorologic instruments to keep records of temperatures, air pressure and movements, humidity, precipitation, and other weather conditions.
In the northern hemisphere the earth's rotation causes winds moving into a low pressure area to form a counterclockwise pattern of rotation. Small, very violent storms with twisting, funnel-like clouds are called tornadoes; large violent storms that form at sea are called hurricanes or typhoons.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* **Use** a weather map or satellite photograph to identify patterns indicating low pressure areas.
In the northern hemisphere prevailing winds generally move from west to east, moving weather systems with them. Jet streams are very strong, high altitude winds. (TA) Flight routes are planned to use or avoid jet streams.	
The relative humidity is the ratio of the amount of water vapor in a given mass of air to the maximum amount it could contain at that temperature.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* **Use** instruments, such as a hygrometer and wet/dry bulb thermometer with a table, to determine relative humidity and dew point.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9 (Continued)	
Energy released by the condensation of water vapor causes air currents that intensify storms.	
Weather is the temporary condition of the temperature, wind, and moisture of the atmosphere at a given place and time.	*Observing, Communicating, Comparing, Organizing* Observe and describe the local weather, and compare it to weather reports from elsewhere. Describe the movement of most major weather systems over North America.
Climate is the long-range condition of temperature, wind, and moisture in a given place over a long period of time.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Gather information on the local climate and compare it with the climate in other localities. Determine the climatic patterns. Gather data from weather maps and collect lists of weather characteristics.
(TA) Many human activities, as well as natural phenomena such as fires, volcanoes, and dust storms, pollute the air with gases, particles, and droplets of liquids (aerosols).[1]	*Observing, Communicating, Comparing, Organizing* Gather and report information from a variety of sources regarding local air quality and sources of major pollutants.
(EC) All human activities that pollute the air are of concern to individuals and society.[1]	
[1]This concept is also developed under "Biological Science—Ecosystems" and "Physical Science—Matter."	
9–12	
Climate and weather are strongly influenced by physical features, such as oceans or mountain ranges.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Gather and report information about how features in the earth's surface influence climate.
Climates are warm near the equator and cold near the poles because the equator receives more direct sunlight during the year.[1]	
Carbon dioxide molecules absorb heat radiation. The increase in atmospheric CO_2 concentration from the burning of fossil fuels may be causing atmospheric warming and could result in major changes in the world's climate.	
Changes in world climate in the past have caused glaciation to advance and recede, with attending effects on land forms, sea level, and life zones.	
[1]This concept is also developed under "Earth Science—Astronomy."	

Earth Science—Oceanography

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
The oceans are the largest water environment on earth.	
Sea water is salty. Water in most lakes and rivers is not salty.	*Observing, Communicating, Comparing* Observe and compare properties of sea water and fresh water, including residue after evaporation.
Water is essential to all forms of life.[1]	
The oceans contain an immense variety of living things.[1]	
People use the oceans in many ways; e.g., as a source of food and minerals, and as a means of transportation, recreation, and waste disposal.	
[1]Concepts in marine biology have generally been included under biological science.	
3–6	
Nearly three-fourths of the earth's surface is covered by water.	
Over nine-tenths of earth's water is salty.	
The ocean bottom has many features comparable to land surfaces; e.g., mountains, canyons, and plateaus.	*Observing, Communicating, Comparing, Organizing, Relating* Using a relief map or globe, identify and compare similar features on land surfaces and the ocean bottom.
The earth's water moves constantly through the water cycle. Water evaporates from the oceans, condenses into clouds, falls to earth as rain or snow, collects in lakes and underground in porous rocks, and eventually reaches the ocean again.[1]	*Observing, Communicating* Observe and describe processes of the water cycle.
The oceans have a great influence on climate.	*Observing, Communicating, Comparing* Observe and compare differences in a region's climate related to its proximity to oceans.
[1]This concept is also developed under "Earth Science—Meteorology."	

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9	
The earth's temperature range allows water to exist on this planet as a solid, a liquid, and a gas.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Predict how conditions on earth would be different if the average surface temperature were below 0° C (32° Fahrenheit) or above 100° C (212° Fahrenheit).
Energy from the sun drives the water cycle by causing evaporation.[1] Distillation is one way of producing pure (fresh) water from salt water. Water dissolves some minerals from the earth's crust and carries them to the ocean or to inland lakes, where the minerals become concentrated as water evaporates. **(TA)** Evaporation is used in concentration and recovery of dissolved minerals.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe and compare residues left when equal volume samples of water from various sources are evaporated. Suggest possible sources of the dissolved solids.
Ocean tides result from gravitational attractions of the sun and the moon.[2] The ocean floor is shaped by currents, volcanoes, and earthquakes. In addition, sediments form as material continuously falls to the bottom of the ocean.[3] Winds cause waves and surface currents. Variations in temperature and salinity cause differences in the density of ocean water. The density, in turn, causes currents. Currents are affected by the earth's rotation. Water, ice, and air carry materials into the oceans and other bodies of water, affecting their properties and their ecosystems.[4] **(EC)** Pollutants carried into oceans and lakes affect living things and need to be controlled by individual behavior and public policy.[4] **(TA)** Ocean waves, tides, currents, and thermal conditions can be harnessed as sources of energy.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Investigate local waste control methods, and evaluate their effects on natural habitats.

See the *California Environmental Education Guide*, Volume 3. Hayward, Calif.: Office of the Alameda County Superintendent of Schools, 1981.

[1]This concept is also developed under "Earth Science—Meteorology" and "Physical Science—Matter."

[2]This concept is also developed under "Earth Science—Astronomy."

[3]This concept is also developed under "Earth Science—Geology and Natural Resources."

[4]Closely related concepts are developed under "Biological Science—Ecosystems," "Earth Science—Meteorology," and "Physical Science—Matter."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

9–12

Energy is transferred where water meets air, land, or subsurface topography.

The geometric shape and polar distribution of electric charge on water molecules account for many of the unusual properties of water (e.g., solvent properties, high boiling point, and high heat of vaporization) and the fact that ice is less dense than liquid water.[1]

Subsurface topography affects and is affected by tides, currents, and waves.

Ocean currents (and changes in currents) affect climates, ecosystems, and human activities.

The use of the oceans and ocean resources is a focus of international conflict as well as international cooperation.

Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying

Identify current international conflicts in the use of oceans and ocean resources, and analyze the reasons for these conflicts; e.g., economics, values, or interpretation of data. Use data that you have obtained and your own values to present and support a position. Use a variety of sources of information, including news articles, zoos, oceanariums, or scientific publications.

Report on the United Nations "Law of the Sea," an international agreement to guarantee that all nations can share the natural resources of the ocean.

See the *California Environmental Education Guide*, Volume 4. Hayward, Calif.: Office of the Alameda County Superintendent of Schools, 1981.

[1]Closely related concepts are developed under "Physical Science—Matter" and "Physical Science—Energy: Electricity and Magnetism."

Physical Science—Matter

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

K–3

Materials and objects, which are forms of matter, have distinctive properties by which they can be described. All of our senses can be used to detect the properties, but we must be cautious in doing so to avoid injury.

Observing, Communicating

Use the senses and an appropriate vocabulary to observe and describe both familiar and unfamiliar objects in terms of properties such as shape, color, texture, odor, and sound (safety precautions).

Observing, Communicating, Comparing

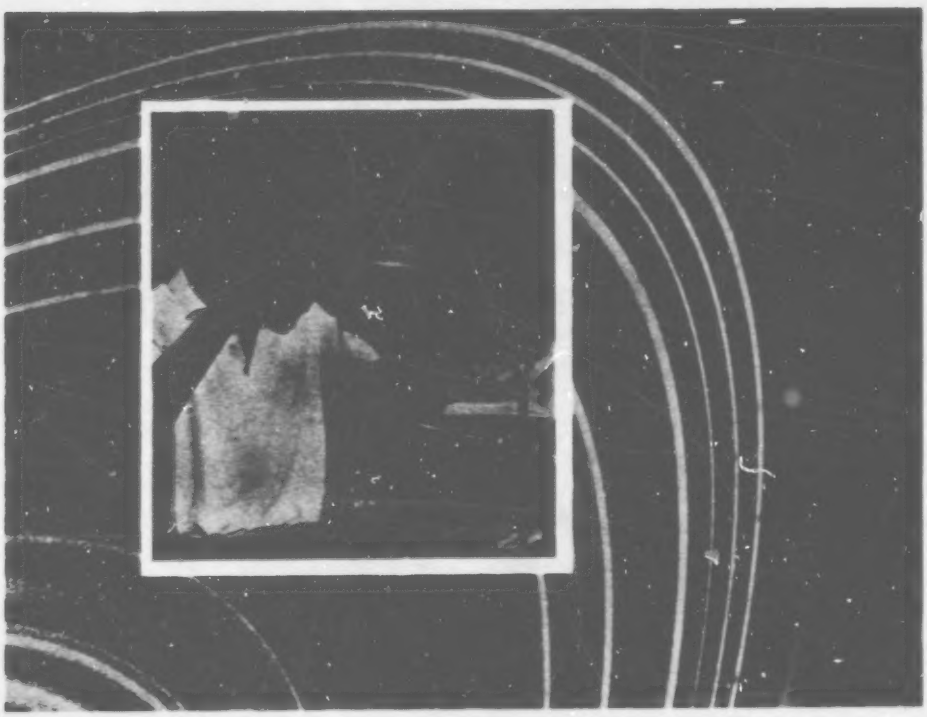
Use the senses and an appropriate vocabulary to compare objects in terms of properties (e.g., length [longer-shorter], weight [heavier-lighter], texture [rougher-smoother], color, shape, odor, sound, or position) or to sequence them [long, longer, longest; heavy, heavier, heaviest]) (safety precautions).

Sort a selection of objects into two groups, using a single property for each group.

It is useful, for many purposes, to classify matter into three groups: solid, liquid, and gas.

Observing, Communicating, Comparing, Organizing

Identify objects as solid, liquid, or gas. Describe the properties specific to each of these three states of matter.



Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
All matter has mass/weight and occupies space (volume).	
Mass/weight and volume can be measured.	*Observing, Communicating, Comparing, Organizing, Relating* Use weighing instruments (spring scale, balance) and metric units to measure and compare mass/weight of objects. Use capacity instruments (graduated containers) and metric units to measure and compare volumes of liquids.
Heating causes many solid substances to melt into liquid and many liquids to evaporate into a gaseous form. The removal of heat causes the opposite reactions, freezing and condensation. These reactions are called phase changes or changes of state.[1] (TA) Phase changes are important in the casting of metals, glass, and some plastics.	*Observing, Communicating* Use the senses to observe and describe changes in properties when heating or cooling causes melting, boiling, evaporation, freezing, and condensation of materials, such as wax, water, or low-melting alloy (safety precautions).
Each chemical element has unique physical and chemical properties.	*Observing, Communicating* Use the senses to observe and describe physical and chemical properties of common chemical elements, such as carbon, oxygen, copper, or iron (safety precautions).
Chemical elements are represented by symbols that are used worldwide.	*Observing, Communicating* Write chemical symbols for some common chemical elements.
Chemical elements are substances that by themselves cannot be changed into other substances (exception: radioactive elements and elements involved in nuclear reactions).	
Chemical compounds are materials that have specific, unique properties that are different from the elements that form them.	*Observing, Communicating, Comparing* Use the senses to observe and describe physical and chemical properties of common compounds, such as salt, sugar, water, sodium bicarbonate, and so forth (safety precautions).
Mixtures are variable combinations of materials (elements and compounds) that usually can be separated without a chemical reaction.	*Observing, Communicating, Comparing, Organizing* Separate the mixtures by such means as physical sorting, evaporation, filtration, or magnetic attraction (safety precautions).
Properties of mixtures usually combine the properties of the substances that make them up and vary according to the amount of each substance present. (TA) Concrete and pigments are applications of this concept.	*Observing, Communicating, Comparing, Organizing, Relating* Predict the variation in properties of mixtures made with varying amounts of the same components; test the prediction (safety precautions).

[1] This concept is also developed under "Earth Science—Meteorology" and "Earth Science—Oceanography."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—6 (Continued)	
Solutions are mixtures that are homogenous (i.e., the mixed particles are evenly distributed and so small that they cannot be seen). (TA) Alloys and lubricants are applications of this concept.	*Observing, Communicating, Comparing* Observe and describe the processes of dissolving and crystallizing (salt or sugar in water) and the escape of gas from carbonated water (gas in water). Compare the solutions with mixtures in which particles of components are visible (sand in water).
When chemical reactions occur, substances (elements and/or compounds) react with each other to form new materials with different properties. (TA) Chemical reactions are used in the production of materials with desired properties; e.g., fibers, medicines, plastics, dyes, or protective coatings.	*Observing, Communicating, Comparing* Observe and describe a variety of chemical reactions, comparing the properties of reactants with those of products (safety precautions).
Many chemical substances are poisonous, flammable, corrosive, and/or very reactive and need to be handled with great care. (TA) Insecticides, cleaning and etching agents, and industrial chemicals are often poisonous and/or corrosive.[2]	*Observing, Communicating* Describe a variety of chemical reactions involving hazardous substances (especially those found in the home). Describe the hazards and precautions for the safe use of each (safety precautions).
Many chemical reactions give off energy. Some give off energy rapidly; e.g., fire or explosion. Rapid reactions are dangerous and must be controlled. (TA) Explosives, fuels, heat engines, and their applications use energy from chemical reactions. (EC) Fire safety and prevention involve individual behaviors and public policy.	*Observing, Communicating, Comparing, Organizing, Relating* Use a thermometer to detect a temperature rise as evidence of energy release in a variety of chemical reactions (safety precautions).
Chemical compounds can be classified according to such characteristics as flammability, toxicity, and solubility in water, and how they react with other substances.	*Observing, Communicating, Comparing, Organizing* Classify chemical compounds according to similar properties; e.g., water solubility, flammability, crystal shape, and the effect on acid-base indicators.

[2]Related concepts are developed under "Biological Science—Human Beings."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9	
Density is the ratio of mass to volume of matter. (TA) Measurement of density is used in analyses of engine coolant, battery acid, or wine.	*Observing, Communicating, Comparing, Organizing* Use instruments and metric units to measure and compare masses of equal volumes of various materials.
	Observing, Communicating, Comparing, Organizing, Relating Use instruments and metric units to measure the mass and volume of objects and materials; compute the density of these objects and materials.
Matter is composed of tiny particles that are in constant motion. In many substances these are called molecules.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe and describe Brownian motion.[1] Explain it by using the theory of moving molecules.
Compressing a gas reduces the space between its molecules. Its pressure and temperature rise, and its volume decreases. (TA) Compression of gases is used in many kinds of heat engines. When a compressed gas is released, its pressure and temperature drop as its volume increases. (TA) Refrigerators and heat pumps are devices using this principle. Electrical forces of attraction hold particles together in liquids and solids. As energy is added to matter, the rate of particle motion (temperature) increases.	*Observing, Communicating, Comparing* Observe and determine the temperature increase when a gas is compressed and the temperature decrease when a gas is released from pressure (safety precautions).

[1]Brownian motion is a random movement of microscopic particles suspended in liquids or gases resulting from the impact of molecules of the fluid surrounding the particle.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued)	
Melting and/or evaporation occur when heat causes particles to speed up enough to overcome the forces of attraction that bind them together. Condensation and freezing occur when heat is removed, the particles slow down, and the attractive forces prevail.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe and describe phase changes, and explain them, using the theory of moving molecules.
Atoms are the smallest particles of chemical elements. Atoms are made up of even tinier particles called electrons, protons, and neutrons. Protons and neutrons form the nucleus, the dense central portion of the atom. Electrons surround the nucleus.	
Atoms normally have equal numbers of positively charged protons and negatively charged electrons, so they are electrically neutral. Atoms or groups of atoms that have lost or gained electrons have a net positive or negative charge and are called ions.	
Chemical compounds are formed when atoms of different elements combine with each other in specific ratios and geometric arrangements. Electrical attractions between electrons of one atom and the nuclei of neighboring atoms create chemical bonds that hold atoms in molecules and crystals.	
Many solid substances are made up of electrically charged particles, called ions, that are bonded by electric attractions into a rigid lattice arrangement that gives crystals their characteristic shape.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Construct crystal models to explain why crystals of a substance assume a consistent, characteristic shape.
In chemical reactions atoms are never created or destroyed, only rearranged into different combinations. Because the mass of atoms is conserved, the products of a chemical reaction have the same mass as the reactants.	*Observing, Communicating, Comparing, Organizing* Measure and compare the mass of reactants and products of a chemical reaction that occurs in a closed system (safety precautions).
Chemical compounds are represented by formulas that indicate the relative numbers of atoms of each element present. Formulas can be written to indicate the structure of molecules of the compound.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Write formulas for some common compounds. Relate the chemical formulas to molecular models and to the compounds themselves.
Chemical equations use formulas to describe the reactants and products of chemical reactions.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Write equations for some simple chemical reactions. Relate the equations to molecular models and to the reactions themselves.
Isotopes are atoms of the same element that have different numbers of neutrons in their nuclei.	

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued)	
Some elements have isotopes that are radioactive; they give off particles and energy and change into other elements of less mass in the process. (TA) Detection of radioactive tracers is used in medicine and industry.	
A certain amount of radioactivity, called background radiation, is a natural part of the environment.	*Observing, Communicating, Comparing, Organizing, Relating* Measure and calculate background radiation, using a radiation detector and timer.
Nuclear reactions involve the rearrangement of protons and neutrons in atomic nuclei to form atoms of different elements. Nuclear reactions convert small amounts of matter into large amounts of energy.[2]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use models or diagrams to describe the process of a nuclear fission chain reaction.
Fission reactions occur when the large nuclei of certain heavy elements are caused to split, forming smaller nuclei (lighter elements) and releasing large amounts of energy. (TA) Nuclear fission reactions are used for electric power generation, propulsion, and weapons.	
Fusion reactions occur when small nuclei of light elements combine at very high temperatures to form larger nuclei of heavier elements, releasing large amounts of energy.[3] (TA) Nuclear fission reactions are used in weapons and will probably be used as a major source of electric power generation in the future.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Use models or diagrams to describe the process of a nuclear fusion reaction.
(EC) Knowledge of how to produce large amounts of energy from nuclear reactions brings with it the need to control the destructive use of the energy.	

[2]This concept is also developed under "Earth Science—Astronomy" and "Physical Science—Energy: Sources and Transformations."

[3]This concept is also developed under "Earth Science—Astronomy."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
Properties of elements are related to the number and "arrangement" of the electrons, protons, and neutrons that compose their atoms. The number of protons in the nucleus (the atomic number) determines what element the atom is.	*Observing, Communicating, Comparing, Organizing* Use the periodic table to show how families of elements are related by common properties.
Properties of chemical compounds are related to the structure of their molecules or crystals. Properties of new compounds can often be predicted. (TA) Prediction of properties is used in synthesis of new compounds having properties needed to serve certain purposes; e.g., plastics, adhesives, medicines, and fuels.	
When ionic crystals are dissolved in water, the ions can move about; and the solution becomes an electrical conductor. (TA) Electrochemical reactions are used in electroplating and electric power sources.	*Observing, Communicating, Comparing, Organizing* Observe and describe the results of tests of electrical conductivity of various solutions; classify the solutions according to their degree of electrical conductivity (safety precautions).
When chemical reactions occur, chemical bonds are broken; and new chemicals form as atoms and are rearranged in new combinations. The beginning substances are called reactants, and the resulting substances are called products. (TA) The entire chemical industry is based on the reorganization of matter in chemical reactions.	*Observing, Communicating, Comparing, Organizing* Observe and describe a variety of chemical reactions, comparing the properties of the reactants with those of the products (safety precautions).
	Observing, Communicating, Comparing, Organizing, Relating, Inferring Use molecular models to describe the rearrangements that occur in a simple chemical reaction.
Chemical reactions can be classified according to the kind of rearrangement of atoms (synthesis, decomposition, replacement); the type of substances reacting (acid-base, oxidation-reduction); energy absorption or release; or other characteristics.	
Chemical reactions generally proceed faster at higher temperatures, as the concentration of reactants is increased, and when the maximum surface area between the reactants is provided. Rates increase because collisions between reacting molecules occur more frequently and more violently because of the above causes.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Measure the rates of chemical reactions by timing the reactions that have a visible end point. Compare the rates of the same reaction when different concentrations of reactants are used and when different temperatures are used (safety precautions).

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9—12 (Continued)	
Energy is required to initiate chemical reactions.	
Catalysts are substances that, without being permanently altered themselves, increase the rate of certain chemical reactions. (TA) Industrial processes, such as petroleum refining or chemical cycles for solar power generation, utilize catalysts.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Compare the rates of catalyzed versus uncatalyzed reactions; e.g., release of oxygen from hydrogen peroxide with or without a catalyst (safety precautions).
(TA) Knowledge of factors affecting the rates of chemical reactions enables reactions to be controlled and made useful. Such knowledge is used in all industrial chemical processes, all processes that involve the burning of fuel, cooking, photography, protection from corrosion, pollution control, and so forth.	
All chemical reactions either absorb or release energy.	*Observing, Communicating, Comparing, Organizing* Observe a variety of chemical reactions and determine which absorb energy and which release energy (safety precautions).
Application of energy to change matter from one chemical form to another generally results in unwanted waste products. When the waste products accumulate or are dispersed into the environment, they create pollution.[2]	*Observing, Communicating, Comparing, Organizing* Research and report on sources, disposal, and control of pollutants in the local or regional area.

[1]Closely related concepts are developed under "Biological Science—Cells, Genetics, and Evolution."

[2]This concept is also developed under "Biological Science—Ecosystems" and "Earth Science—Meteorology."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9—12 (Continued)	
(TA) Some radioactive isotopes are useful in medicine, industry, and research. They all give off radiation that can be harmful or lethal to living things, especially if they are ingested.[3]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Investigate the use of radioisotopes in medicine, industry, and research, including precautions in shipping, use, and disposal.
Each radioactive isotope gives off its radiation at a specific rate. The half-life of an isotope is the time taken for half of its atoms to give off their radiation. (TA) Knowledge and measurement of half-lives are used to determine the age of rocks and of the remains of living things and to predict how long radioactive waste materials will remain hazardous.[4]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Given the half-life of an isotope: 1. Calculate how much of a given sample will remain after one, two, three, and four half-lives of time have elapsed. 2. Calculate how long it will take until only one-one-thousandth (1/1000) of the sample remains.
Knowledge of exactly how radiation damages cells is incomplete. Determination of minimum safe levels of radiation exposure is based on statistical interpretations and risk/benefit value judgments.	
(TA) Nuclear reactions can be used: (1) in extremely destructive weapons; (2) as a source of energy to generate electricity and to propel large vehicles; and (3) as a source of useful radioactive isotopes.	
Nuclear reactions produce radioactive waste products that are difficult to dispose of and dangerous to living things. Nuclear reactions that get out of control may disperse wastes over a wide area.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Describe some proposed methods of radioactive waste disposal, giving the advantages and disadvantages of each.
(EC) Production and use of radioisotopes necessitate techniques and policies for managing the materials with minimum risk to living things.	
(TA) Fusion of hydrogen (vast amounts of which are combined with oxygen in the water of the oceans) into helium offers hope of being a long-range source of energy, provided major technical problems can be solved.	
(EC) Development of long-range energy sources for future generations is a responsibility of present generations.[5]	

[3]Related concepts are developed under "Biological Science—Human Beings."

[4]This concept is applied under "Earth Science—Geology and Natural Resources" and "Biological Science—Cells, Genetics, and Evolution."

[5]Closely related concepts are developed under "Earth Science—Geology and Natural Resources" and "Physical Science—Energy: Sources and Transformations."

Physical Science—Mechanics

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
K–3	
Most objects fall toward the earth when they are released.	*Observing, Communicating* Observe and describe the behavior of falling objects (safety precautions).
Machines are devices that make some tasks easier.	*Observing, Communicating, Comparing* Compare the effort needed to perform a task with or without using a simple machine.
Rubbing objects together makes them warm.	*Observing, Communicating* Observe and describe the heating effect produced by rubbing objects together (safety precautions).
Events can be sequenced in time.	*Observing, Communicating, Comparing, Organizing* Place descriptions or pictures of a series of events in chronological order.
Distance, position, and motion can be used to describe and classify objects.	*Observing, Communicating, Comparing* Describe the location of an object in such a way that another person can find it.
3–6	
A force is a push or a pull.	
Force is necessary to move a stationary object, to bring a moving object to rest, or to change the direction of a moving object.	*Observing, Communicating, Comparing, Organizing* Use a weighing instrument to measure the force needed to move objects or to stop moving objects.
Gravity is a force that attracts all objects toward the center of the earth.[1]	
Weight is the measure of the force of gravity pulling an object toward the center of the earth.[1]	*Observing, Communicating, Comparing, Organizing* Use a weighing instrument and metric units to weigh various objects.
Simple machines—levers, wheels, pulleys, wedges, inclined planes, and screws—make some tasks easier by changing the direction or amount of force or distance. (TA) Most mechanical devices incorporate one or more simple machines.	*Observing, Communicating, Comparing, Organizing* Measure and compare forces that must be exerted with or without using simple machines to accomplish a variety of tasks.
Work involves using force to move something.	

[1]This concept is also developed under "Physical Science—Matter."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6 (Continued)	
Friction is a force that resists the motion of objects.	*Observing, Communicating, Comparing, Organizing, Relating*
Friction is used in the operation of brakes, tires, and fasteners (e.g., nails and screws). Friction with air slows the space shuttle so it can land.	Measure and compare forces needed to move an object with or without the use of friction-reducing devices.
Time and distance can be measured. (TA) Clocks, distance-measuring devices, radar, and maps involve measurements of time and distance.	*Observing, Communicating, Comparing, Organizing*
	Use appropriate instruments to measure and record time intervals and distances traveled.
Speed is a measure of the distance an object travels in a given time. (TA) A speedometer measures speed by relating time and distance.	*Observing, Communicating, Comparing, Organizing, Relating*
	Calculate the speed of moving objects, using measurements of time and distance traveled.
6–9	
Work is accomplished when a force moves a resisting object for a distance in the direction of the force.	*Observing, Communicating, Comparing, Organizing, Relating*
	Use metric units to measure force and distance; compute work done in moving an object.
Power is a measure of the work that is done in a unit of time.	*Observing, Communicating, Comparing, Organizing, Relating*
	Calculate the power required to perform a given amount of work in a given time; e.g., to lift a 1000 kilogram elevator 30 meters in 10 seconds.
Complex machines are made up of simple machines.	*Observing, Communicating, Comparing, Organizing*
	Identify examples of simple machines that make up a complex machine.
Frames of reference for size, position, direction, time, distance, and motion are relative, not absolute.	
Pressure is force per unit of area on which the force acts.[1]	*Observing, Communicating, Comparing, Organizing, Relating*
	Measure force and the area on which it acts; calculate pressure.
Mass is a measure of quantity of matter. The greater the mass of an object, the greater the earth's gravitational attraction for it and, thus, the greater its weight.	*Observing, Communicating, Comparing, Organizing*
	Measure the mass of objects, using metric units.

[1]This concept is also developed under "Physical Science—Matter" and "Earth Science—Meteorology."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
Acceleration is a change in speed and/or direction of motion due to the application of a force.	
Inertia is the tendency for an object to resist changes in its motion. (TA) A flywheel utilizes inertia to store energy and release it as needed.	
Gravity is a force of attraction between all objects or particles of matter. The force of gravity increases with the mass of objects and decreases as the distance between them is increased.[1]	*Observing, Communicating, Comparing, Organizing, Relating* Calculate the force of gravitational attraction between two objects, given their masses and the distance separating them, using the formula: $F = \frac{m_1 m_2}{d^2}$
When friction occurs, the kinetic energy of an object is converted into molecular motion (heat), thus slowing the object.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe and describe the slowing down of a device due to friction. Explain how and where the mechanical energy is converted into heat by friction.
There are a variety of ways to reduce or increase friction. (TA) Lubricants, alloys, coatings, and magnetic fields are used to reduce friction.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Examine the way in which a machine operates, and suggest ways in which friction might be reduced. Examine a variety of devices that depend on friction for their effectiveness; e.g., fasteners, tires, shoe soles, brakes, or parachutes. Suggest ways in which these devices might be improved.

[1]This concept is applied under "Physical Science—Matter," "Earth Science—Astronomy," and "Earth Science—Oceanography."

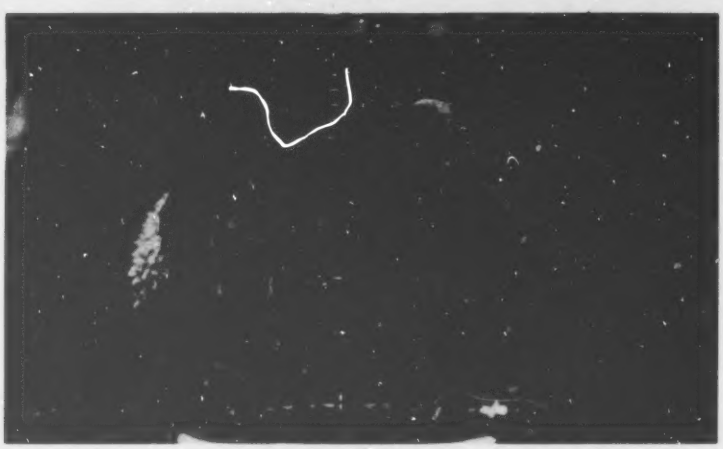
Physical Science—Energy: Sources and Transformations

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Energy is necessary to do work and to cause changes in matter.[1]	*Observing, Communicating, Comparing, Organizing, Relating* Observe and describe examples of the use of energy to do work and produce changes in matter (safety precautions).
Energy takes many forms; e.g., heat, light, electricity, sound, and motion of objects. These forms can be converted from one into another.	*Observing, Communicating* Observe and describe a variety of energy-converting devices; e.g., radio, toaster, heater, record player, movie projector, or car (safety precautions).
Every energy conversion involves some loss of useful energy to the surroundings, usually as heat.	*Observing, Communicating* Observe and describe heat loss in a variety of energy transformations; e.g., motors, light fixtures, television, tires, or dry cell (safety precautions).
Sources of useful energy include sunlight, earth's heat (geothermal), wind, water flow, nuclear reactions, and fossil fuels. The energy stored in fossil fuels came originally from the sun.[1]	*Observing, Communicating, Comparing, Organizing* Trace to the original source the energy used by a variety of devices.
Sunlight gives rise to a number of renewable sources of energy, including plant tissue, wind, and falling water. (TA) Farming and power generation from wind or falling water depend on solar energy.[2]	

See the *California Environmental Education Guide*, Volume 2. Hayward, Calif.: Office of the Alameda County Superintendent of Schools, 1981.

[1]Closely related concepts are developed under "Earth Science—Geology and Natural Resources."

[2]Closely related concepts are developed under "Biological Science—Cells, Genetics, and Evolution" and "Biological Science—Ecosystems."



Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9	
Potential energy is stored energy that can be released to do work; e.g., matter that can fall, chemical substances that can react, electrically charged objects that can attract or repel each other, and compressed springs. (TA) Clocks, hydroelectrical power generation, heat engines, batteries, and a roller coaster all involve conversions between potential and kinetic energy.	*Observing, Communicating, Comparing* **O**bserve and describe a variety of examples of potential energy; predict ways in which the energy could be released.
Kinetic energy is energy in the form of motion of an object.	
Energy is neither created nor destroyed during conversions, but some energy is dissipated, usually as increased molecular motion, and is no longer usable.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* **O**bserve and describe a variety of energy transformations, identifying and inferring ways in which energy is dissipated.
Conversion of energy from one form to another always has some effect on the surroundings.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* **O**bserve and infer the environmental effects (e.g., noise, heat, pollution, changes to the ecosystem) of a variety of energy conversions.
(EC) Concern for the environmental effects of energy transformations has implications for individual behavior and public policy.	
(TA) We depend heavily on fossil fuels for our current energy needs, especially for power generation, transportation, and space heating. Fossil fuels were formed long ago from buried plants and animals. Since we are using these fuels up faster than they are being formed, other energy sources will need to be developed.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* **G**ather data on the rates of use and estimated reserves of various fossil fuels. Estimate the number of years it will take for each source to be exhausted if the rate of usage remains the same or is increased or decreased by 50 percent.
(EC) Care and conservation in the use of energy and in the choice of energy sources involve personal behaviors as well as public policy.[1]	

[1]Closely related concepts are developed under "Biological Science—Ecosystems" and "Earth Science—Geology and Natural Resources."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
All sources of energy we know of derive ultimately from electrical, gravitational, and nuclear forces.[1]	
The efficiency of an energy conversion is the fraction of energy put in that results in useful work, or the desired form of energy output.	*Observing, Communicating, Comparing, Organizing, Relating* Given measures of energy input and output in a given device or transformation, calculate the efficiency.
(TA) One way to conserve useful energy is to improve the efficiency of conversion processes.	*Observing, Communicating, Comparing, Organizing, Relating* Gather data on the efficiency of various means of energy generation, transmission, and end-use. Calculate the overall efficiency (e.g., coal burns to make steam to generate electricity transmitted 50 km to a home where the electricity is used to recharge a battery used to power an electric car).
(EC) One way to conserve useful energy is to be careful in choices of how to use energy and to be careful not to waste it.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Identify and make quantitative estimates of personal energy use; identify means of reducing energy use with or without major changes in a person's life-style.
(EC) To ensure that we have adequate energy sources in the future, we must shift our dependence to renewable or inexhaustable energy sources.[2]	
Environmental effects and safety must be considered in selecting and exploiting energy sources.[2]	

[1] This concept is also developed under "Physical Science—Matter."

[2] This concept is also developed under "Earth Science—Geology and Natural Resources" and "Earth Science—Meteorology."

S 4/1

Physical Science—Energy: Heat

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

K–3

Heat comes from a variety of sources, such as fire or the sun.[1]

Observing, Communicating

Observe and describe different sources of heat; e.g., heater, stove, fire, sun, or friction (safety precautions).

The skin is the main organ of the body that senses heat.[2]

Observing, Communicating, Comparing

Using the sense of touch, observe, describe, and sequence objects according to how hot they are (safety precautions).

Heat is essential to living things. Intense heat or cold causes damage to objects and living things; e.g., touching hot or very cold things burns the skin.

Observing, Communicating

Observe and describe objects and organisms that have been damaged by heat or cold.

See the *California Environmental Education Guide*, Volume 1. Hayward, Calif.: Office of the Alameda County Superintendent of Schools, 1981.

[1]Closely related concepts are developed under "Earth Science—Astronomy" and "Earth Science—Meteorology."

[2]This concept is also developed under "Biological Science—Human Beings."

3–6

Temperature is a measure of how hot things are. It is measured by means of a thermometer.[1]

Observing, Communicating, Comparing, Organizing

Measure temperatures using a Celsius thermometer. Use tables and graphs to record temperatures. Calculate temperature differences. Order objects by measured temperature.

Heating causes most materials to expand. (TA) Expansion joints in bridges and thermometers use this principle.[1]

Heat can be used to do work. (TA) Steam engines, turbines, and internal combustion engines use heat to do work.

Heat moves from warmer to cooler areas by the following means: conduction—heat spreads through a solid; convection—heated liquid or gas moves; radiation—heat waves radiate from a warm object. (TA) Heating and cooling devices use conduction, convection, and radiation.

Observing, Communicating, Comparing, Organizing, Relating

Observe and describe examples of conduction, convection, and radiation. Conduct an experiment to compare the heat conductivity of various materials (safety precautions).

Insulators are materials that tend to block the flow of heat. (TA) Insulation is important in homes, refrigerators, and spacecraft. Clothing acts as an insulator and helps maintain body temperature.

Observing, Communicating, Comparing, Organizing, Relating

Observe and describe a variety of insulating materials. Conduct an experiment to compare insulating properties of various materials (safety precautions).

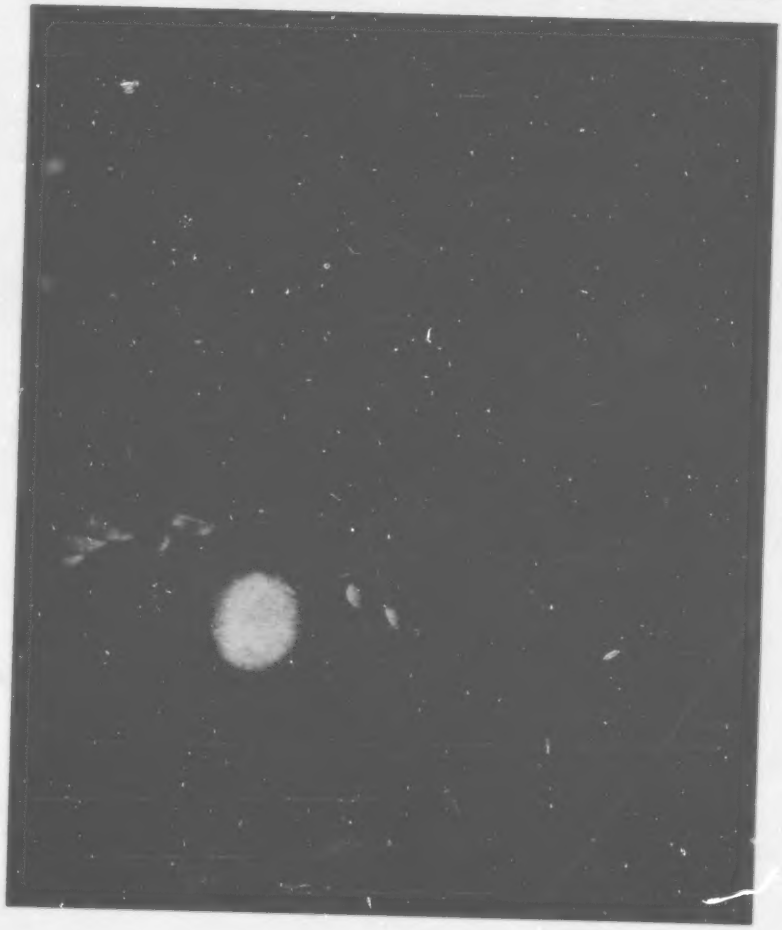
[1]These and other closely related concepts are developed under "Physical Science—Matter" and "Earth Science—Meteorology."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9	
Temperature is a measure of motion (kinetic energy) of molecules.[1]	
By increasing the motion of molecules, heat causes the average distance between them to become greater, causing the expansion of matter.[1] The amount of expansion varies with the material. (TA) Thermostats and thermometers work because heat expands matter in a predictable way.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe, measure, and describe the expansion of various objects when they are heated; explain thermal expansion, using kinetic molecular theory.
Heat capacity is the amount of heat it takes to produce a given temperature rise in a given mass of a substance. (TA) High heat capacity permits the storage of heat in water, cracks, and certain other materials.	*Observing, Communicating, Comparing, Organizing, Relating* Measure the mass and temperature change of water; calculate the heat lost or gained.
Conduction occurs when hotter (faster-moving) molecules bump into cooler (slower-moving) molecules, transferring some of their energy. (TA) Soldering irons and stoves use heat conductivity.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe and describe examples of heat transfer by conduction, convection, and radiation; explain heat transfer using kinetic molecular theory.
Convection occurs when a mass of heated gas or liquid moves (usually rising, because it is less dense) to a cooler area. (TA) Space heating systems involve convection.[2]	
Infrared (heat) radiation consists of electromagnetic waves, longer than light waves, that move through some kinds of matter and through a vacuum.	
Insulators inhibit heat transmission by being poor conductors, by preventing convection, and by reflecting infrared radiation. (TA) Insulation is important in living space, appliances, spacecraft, and so forth.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Experiment to determine the relative effectiveness of various insulating materials in various heat transfer situations; sequence the insulators by their effectiveness.

[1]This concept is also developed under "Physical Science—Matter."

[2]This concept is developed under "Earth Science—Meteorology" and "Earth Science—Oceanography."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
(TA) Reducing drafts and air circulation near doors and windows and using insulation are ways of conserving energy used for space heating.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Identify sources of home heat loss and the cost of remedies, and determine some cost-effective conservation measures.
(TA) Heat engines convert energy from a variety of sources into molecular motion, usually by evaporating liquids and/or heating and compressing gases. Molecular motion is subsequently converted into mechanical motion by pistons, turbines, and so forth.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* Design and describe the operation of a heat engine.
(TA) Any temperature difference, such as exists between the ocean bottom and its surface layers, is a possible source of energy.	



Physical Science—Energy: Light

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

K–3

Light comes from a variety of sources. The sun is the source of daylight.	*Observing, Communicating* Observe and describe many sources of light; i.e., lamp, candle, flashlight, sun (safety precautions).
Light can be described, sequenced, and classified by characteristics such as color and intensity.	*Observing, Communicating, Comparing, Organizing* Observe, describe, and sort objects according to their color. Observe and order light sources according to their intensity (safety precautions).
Light travels through some things and not through others.	*Observing, Communicating, Comparing, Organizing* Observe, describe, compare, and classify materials according to their ability to transmit light.
Objects that block light cast shadows.	*Observing, Communicating, Comparing* Observe and describe shadows made by various light sources and objects. Match shadows to objects used to create them.
Light is reflected.	*Observing, Communicating, Comparing* Use a mirror to show that light can be reflected. Compare light reflected from light and dark surfaces (safety precautions).
The eye is the organ of the body that receives light. Looking directly at a strong source of light, such as the sun, can injure the eyes and even cause blindness.[1]	*Observing, Communicating* Look at places which receive different amounts of light. Observe your eye in a mirror (safety precautions).

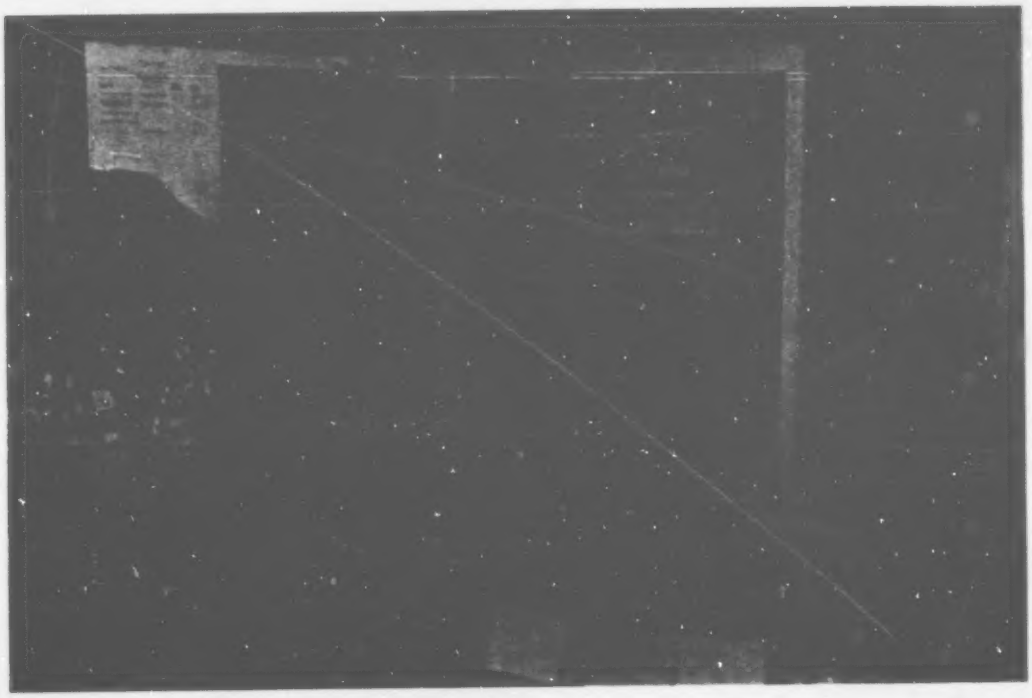
[1]Related concepts are developed under "Biological Science—Human Beings."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Very hot objects radiate light as well as heat. (TA) Incandescent light bulbs use hot filaments to produce light.	*Observing, Communicating, Comparing* Observe, describe, and compare the intensity and color of various light sources; e.g., electrical filaments, flares, or stars (safety precautions).
White light is a mixture of colors that can be separated into a spectrum of colors by a prism.	*Observing, Communicating* Using a prism, observe and describe the spectrum produced by white light (safety precautions).
Colored objects absorb some of the colors of white light and reflect or transmit others. (TA) Paints, dyes, and traffic signals appear colored because they absorb some colors of light.	
The eye is sensitive to a limited range of colors called visible light.[1]	*Observing, Communicating, Comparing, Organizing* Observe, describe, compare, and classify objects and light sources of various colors.
Intense light can cause blindness or impaired vision.[1]	
Light travels in straight lines very rapidly from its source. (TA) Communication by light signals is practical because light travels very rapidly through some materials.	
When light is reflected from a mirror, the angle of incidence equals the angle of reflection.	*Observing, Communicating, Comparing* Observe and compare the angles of incidence and reflection of a beam of light reflected from a flat mirror.
When light strikes an object, part of it is absorbed and changed to heat. (TA) A solar cooker converts light to heat.	*Observing, Communicating, Comparing* Measure and compare the soil surface temperature in both light and shade.
Refraction occurs when the path of light is bent as it moves from one medium to another; e.g., from air to water or glass.	*Observing, Communicating* Observe and describe examples of refraction of light.
Concave mirrors can focus light by reflection. Lenses can focus light by refraction.	*Observing, Communicating, Comparing* Measure the focal length of a convex lens and a concave mirror.
(TA) Cameras, telescopes, microscopes, projectors, and the eye use lenses to focus images of objects.	

[1]Related concepts are developed under "Biological Science—Human Beings."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9	
Light waves behave much as water waves do when they are reflected, refracted, and diffracted.	
The tiniest quantity of light is called a photon.	
Light intensity and lightwave frequency can be measured. (TA) A light meter measures light intensity.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Measure and compare light intensity in various situations, using a light meter.
Lenses can compensate for eye defects that cause nearsightedness, farsightedness, and image distortion.[1]	*Observing, Communicating, Comparing* Observe and describe how the appearance of objects is affected by various visual defects.
Light can cause chemical reactions to occur. (TA) Photography and blueprinting employ light-triggered chemical reactions.	
Chemical changes in the retina cause nerve impulses to the brain, where meaning is given to what we see.[1]	

[1]Related concepts are developed under "Biological Science—Human Beings."



Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

9–12

Light energy consists of electromagnetic waves that travel through a vacuum at about 300 000 kilometers per second (186,000 miles) and through some kinds of matter nearly as fast. (TA) Optical fibers are useful to transmit and direct light.

Color is our perception of the frequency of light waves within the limited range to which our eyes are sensitive, red having lower frequency (longer wave length) and blue having higher frequency (shorter wave length).

Infrared waves, radio waves, and microwaves have lower frequency (longer wave lengths) than visible light. Ultraviolet rays, X-rays, and gamma rays have higher frequency (shorter wave length) than visible light. Shorter wave lengths carry more energy. Electromagnetic energy is used in many ways; e.g., X-rays, microwave ovens, and infrared detection.

(EC) Widespread applications of electromagnetic radiation necessitate precautions to protect living things from adverse effects.

Observing, Communicating, Comparing, Organizing, Relating

Given the distances involved, calculate the time it takes for light to reach the earth from the moon, other planets, the sun, and the next nearest star. Calculate how long it takes a radio signal to travel from Moscow to San Francisco via satellite.

Observing, Communicating

Observe and describe line emission spectra, using a diffraction grating.

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9—12 (Continued)	
(TA) By controlled variation of frequency and/or intensity, light waves (and radio and microwaves) can be used to transmit information; e.g., radio, television, or radar.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring*
(EC) Electronic telecommunications media require regulation to prevent abuses affecting large numbers of people.	**Observe** and describe situations and devices in which light is used in transmitting information.
A laser produces a very intense beam of parallel light waves that are coherent. (TA) Laser beams are useful in a variety of ways; e.g., communications, surgery, weapons, or holography.	
Some properties of light, such as refraction, are best explained by thinking of light as waves. Some properties, such as the photoelectric effect, are best explained if one thinks of light as a stream of tiny particles. Some properties, such as reflection, are explained well by either model.	
When light passes through a gas, certain frequencies are absorbed. The resulting spectrum has dark lines that permit identification of the gas. (TA) Spectra of chemical elements are used in analysis of gases and the study of stars.	
Some of the light absorbed on a surface is radiated as heat. If the heat is prevented from escaping (e.g., by a window or by the atmosphere), the greenhouse effect occurs. (TA) Greenhouses and solar heating systems use this principle.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying* **Invent**, describe, and demonstrate a device to produce the greenhouse effect.
(TA) The development and use of more efficient lighting sources are ways of conserving energy; e.g., fluorescent versus incandescent lighting.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* **Measure** and compare the light output of various light sources that have the same rate of energy usage.

[1]This concept is also developed under "Earth Science—Meteorology."

Physical Science—Energy: Electricity and Magnetism

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

K–3

Magnets attract some objects.

Observing, Communicating

Observe and describe the effect of a magnet on various objects, including other magnets.

Objects can be sorted according to whether or not they are attracted to a magnet.

Observing, Communicating, Comparing, Organizing

Sort objects according to whether or not they are attracted by a magnet.

(TA) Electricity is used to provide light and heat and to run machines, television sets, radios, telephones, and so forth.

Observing, Communicating, Comparing, Organizing

Observe, describe, and classify a variety of household and school devices that use electricity (safety precautions).

3–6

Magnets have two poles, north and south. Opposite poles attract; like poles repel each other.

Observing, Communicating, Comparing

Observe, describe, and compare the actions of magnets by moving opposite and like poles toward each other.

The earth acts like a large magnet. (TA) Magnetic compasses utilize the earth's magnetic field to determine direction.[1]

Observing, Communicating

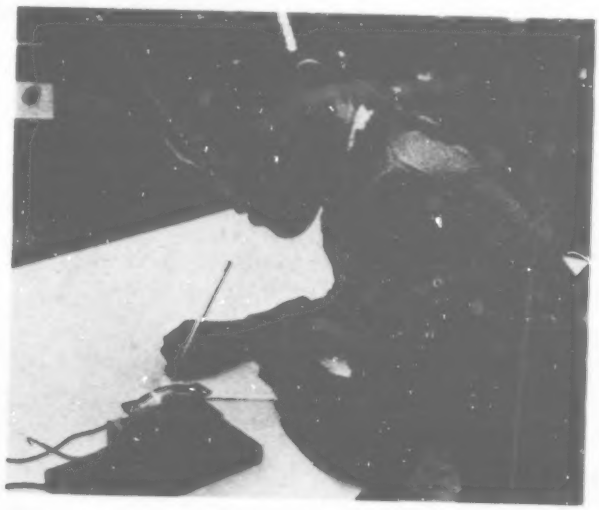
Observe and describe the behavior of a magnetic compass.

A magnetic field, capable of exerting force, extends from the poles of a magnet.

Observing, Communicating, Comparing

Observe, describe, and compare magnetic fields of various magnets as revealed by means of iron filings.

[1]Related concepts are developed under "Earth Science—Geology and Natural Resources."



Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3—6 (Continued)	
A magnetic field produces an electric current in a conductor that moves through it. An electric current produces a magnetic field. (TA) Generators, motors, and electromagnets use magnetic fields to produce electricity and vice versa.	*Observing, Communicating, Comparing, Organizing, Relating* Using a dry cell, nail, and wire, create and demonstrate an electromagnet.
There are two kinds of electric charges, positive (+) and negative (–). Like charges repel each other; unlike charges attract.	*Observing, Communicating, Comparing* Observe and describe the behavior of electrically charged objects moving toward or away from one another.
An electric current can be made to move along a conductor in a complete circuit.	*Observing, Communicating, Comparing, Organizing, Relating* Using a dry cell, wire, and flashlight bulb, create a circuit that will light the bulb.
Materials can be classified according to how well they conduct electricity.	*Observing, Communicating, Comparing, Organizing, Relating* Experiment with various materials to complete an electrical circuit, classifying materials as conductors or nonconductors.
Electric current can harm or kill living things and must be carefully controlled.[2]	*Observing, Communicating* Identify and describe electric shock hazards to be avoided at home, school, and so forth.
[2]Related concepts are developed under "Biological Science—Human Beings."	
6–9	
An electric current that moves back and forth in a conductor (alternating current) gives off waves of electromagnetic radiation. (TA) Radio, television, microwaves, and radar are devices that use waves produced by alternating current.	*Observing, Communicating, Comparing, Organizing* Observe and describe the effect on radio reception when a car is near electrical transmission lines.
Electrons, which are negative (–), and protons, which are positive (+), are tiny particles of matter that carry electric charges.[1]	
An electric current is a movement of electrons along a conductor. (TA) Wires and printed circuits are used to conduct electricity.	
[1]This concept is also developed under "Physical Science—Matter."	

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6—9 (Continued)	
Conductors offer resistance to the movement of electric current, causing some energy to be converted to heat. (TA) Electric heaters, toasters, incandescent light, fuses, and circuit breakers, and electric arc welding use heat caused by resistance to electric current.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Observe and describe evidence for the release of heat as electric current is passed through a conductor.
The amount of electric current depends on the force or potential driving it and the resistance of the conductor.	
Electrical potential (volts), current (amperes), and resistance (ohms) can be measured.	*Observing, Communicating, Comparing, Organizing* Using appropriate meters, measure electrical potential, current, and resistance in a simple circuit.
(TA) Electrical energy used in households in the United States is generally 110 or 220 volt, 60-cycle alternating current.	*Observing, Communicating* Read and interpret labels on electrical appliances.
Electrical impulses travel along a conductor at the speed of light. (TA) The high speed of electrical impulses makes electrical energy transmission and telegraph and telephone communication practical.	
Metals conduct electricity well because some electrons are free to move about in metallic crystals. Water with dissolved minerals conducts electricity because charged particles called ions can move through the water.[1]	

[1]Closely related concepts are developed under "Physical Science—Matter."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
One problem with electricity is that it must be used as it is produced or else converted into some other form for storage; e.g., chemical energy in a battery.	
(TA) More efficient generation, transmission, and end-use conversion of electricity are ways of conserving energy.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* Organize energy-consumption data for several brands of one type of appliance; e.g., refrigerator. Calculate and compare the annual energy consumption of various appliances.
Electrons from a source such as a hot wire filament can be caused to flow rapidly in a stream through a vacuum. When such fast-moving electrons strike atoms, X-rays, light, and other electromagnetic radiation are given off. (TA) This effect is applied in such devices as X-ray tubes, fluorescent tubes, and cathode ray tubes for computers and television sets.	
Some materials, called superconductors, lose all of their electrical resistance when they are chilled to very low temperatures. (TA) This effect makes possible very strong electromagnets, efficient transmission of energy, and sensitive magnetometers.	*Observing, Communicating* Observe and describe unusual properties of materials at very low temperatures.
By varying the frequency and intensity of electrical impulses, they can be used to transmit information. (TA) All telecommunication is based on this principle.	
(TA) Properties of semiconductors enable them to be used for storing enormous amounts of information in tiny spaces and for processing and retrieving the information in very short times. Calculators and computers use semiconductors.	

Physical Science—Energy: Sound

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*

K–3

Sound comes from many sources.

Observing, Communicating, Comparing

Observe and describe sounds from different sources. Match the sounds with their sources.

Sounds can be described, sequenced, and classified by their characteristics, such as pitch, loudness, and quality.

Observing, Communicating, Comparing, Organizing

Group sounds according to some quality. Sequence sounds according to their pitch and loudness.

Sounds travel through many things.

Observing, Communicating

Make a telephone with two small cans or cups and a connecting wire or string.

Sounds, such as echoes, are reflected from surfaces. Sounds fade away as they are absorbed.

Observing, Communicating

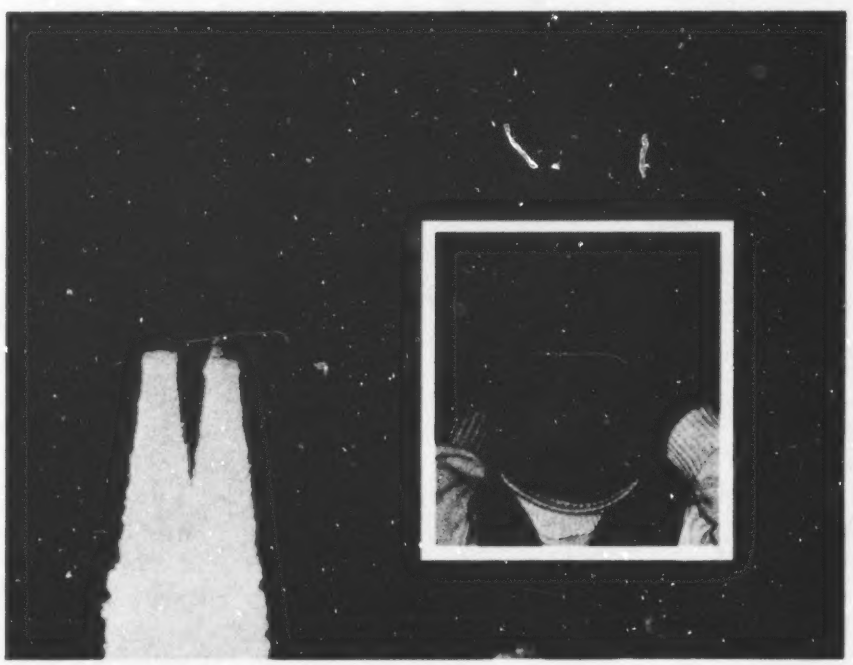
Observe and describe echoes.

The ear is an organ of the body that receives sounds.[1]

Very loud sounds can damage the ear.[1]

The larynx, or voice box, is the main organ the body uses to produce sounds.[1]

[1]Related concepts are developed under "Biological Science—Human Beings."



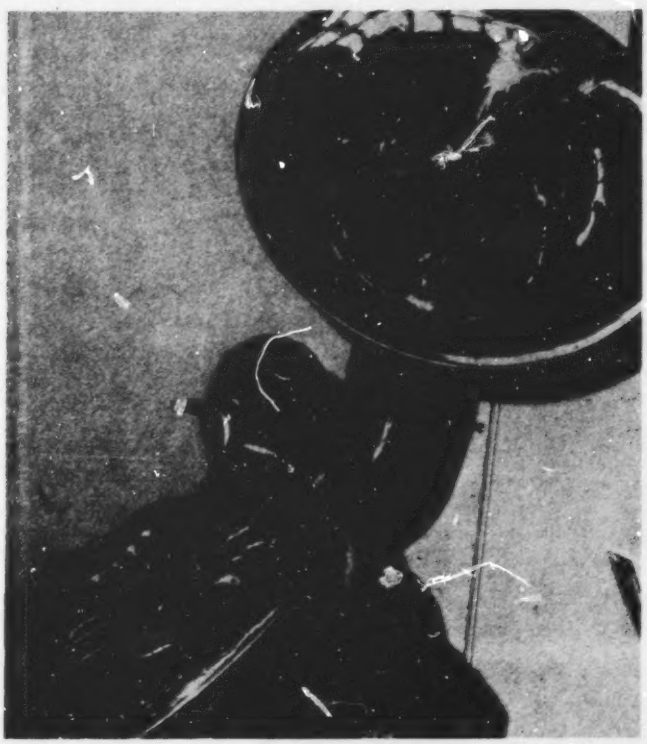
Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
3–6	
Vibrating objects produce sound by causing vibration in whatever they touch.	*Observing, Communicating, Comparing* Observe and describe a variety of sound sources. Match sounds to sources.
Sound sources can often be caused to vibrate by striking, plucking, or blowing. (TA) Musical instruments, whistles, and sound signals produce something that vibrates.	
Sound vibrations occur in wavelike patterns.	
The pitch of sound depends on the number of vibrations per second (frequency). (TA) Musical instruments are designed to produce controlled frequencies of sound waves.	*Observing, Communicating, Comparing, Organizing, Relating* Sequence sound sources by pitch. Create or adjust a sound source to match a given pitch.
The loudness of sound depends on the intensity of the vibrations.	
The quality of sound depends on the mixture of its frequencies. (TA) Musical instruments are designed to produce pleasing mixtures of frequencies.	*Observing, Communicating, Comparing, Organizing* Classify sounds according to their quality.
Sound travels through solids, liquids, and gases at different speeds. Sound does not travel through a vacuum. The speed of sound through air at sea level is about 330 meters per second, or 740 miles per hour.	*Observing, Communicating, Comparing, Organizing, Relating* Estimate how long it will take the sound of an explosion to reach places that are 1, 5, and 10 km (.6, 3, and 6 miles) away.
Sounds can be controlled by directing, reflecting, and absorbing them and by varying their pitch and loudness. (TA) Music, sonar, and communication by sound signals all depend on controlling sound waves.	
The eardrum vibrates when sounds strike it.[1]	
Two ears are better than one for locating the source of sound.[1]	*Observing, Communicating, Comparing* Compare the ability to locate sound sources using one ear versus using both ears.
The human ear is sensitive to a limited range of frequencies. Instruments and some animals can detect sound frequencies that are outside the range of human hearing.[1]	
Frequent or prolonged exposure to very loud sounds can cause permanent hearing impairment.[1]	*Observing, Communicating* Identify and describe situations in which ear protection should be used.
(EC) Individual behaviors conducive to hearing safety for oneself and others are important.	*Observing, Communicating* Identify behaviors that may damage hearing—one's own and others'.

[1]Related concepts are developed under "Biological Science—Human Beings."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
6–9	
Sound is a form of energy consisting of rapid back-and-forth (compression/rarefaction) waves of molecules in solids, liquids, and gases.	
Pitch is our perception of the frequency of sound waves. The higher the pitch, the higher the frequency and the shorter the wave length.[1]	*Observing, Communicating, Comparing, Organizing, Relating, Inferring* **O**bserve and describe a sound source in operation; predict the effect of various modifications on the pitch produced; test the prediction.
Loudness is our perception of the intensity (amplitude) of sound waves. The greater the difference in pressure between the compression and the rarefaction, the louder the sound. Loudness is measured in decibels.[1]	
(EC) Noise pollution resulting from technological applications needs to be controlled by individuals and by society.	
Sound waves are bent, or refracted, and reflected as they move from one medium to another. (TA) Knowledge of sound refraction is applied in sonar and echolocation of oil deposits.	
Musical tones are sounds that have a single dominant frequency, usually accompanied by related (harmonic) frequencies or overtones.	
Sound stimuli received by the ears are transmitted to the brain, where meaning is interpreted.[1]	*Observing, Communicating, Comparing* **O**bserve, describe, and compare the sounds of words that have the same meaning in several languages.
The larynx, controlled by nerve impulses from the brain, produces sounds as we pass air through it.[1]	

[1]Related concepts are developed under "Biological Science—Human Beings."

Knowledge: Science Concepts, Technological Applications (TA), and Ethical Concerns (EC)	*Thinking Processes and Manipulative and Communicative Skills*
9–12	
Some objects have natural frequencies at which they can be caused to vibrate.	*Observing, Communicating, Comparing, Organizing, Relating, Inferring, Applying*
	Invent and demonstrate a device that uses resonance to amplify sound.
Resonance, or sympathetic vibration, occurs when the sound of a particular frequency causes an object to start vibrating at that frequency. (TA) Musical instruments are designed to utilize resonance. Airplanes and other machinery are designed to avoid metal fatigue caused by resonance.	Determine the natural frequencies of vibrating objects, such as a playground swing or a cup of coffee. Find ways to change the natural frequencies.
The Doppler effect occurs when we hear a higher pitch from an approaching sound source and a lower pitch as the source moves away. (TA) Movement of underwater objects is detected by sonar, using the Doppler effect.	
(TA) Very high frequency sound (ultrasonics) has a variety of applications in medicine and industry.	



100

Ethical Issues in the Science Classroom

Scientists are often among the first to ponder ethical issues arising from scientific and technological discoveries. They must evaluate the potential implications of findings for society as a whole. Science teachers can create classroom discussions and debates that allow students to appreciate the benefits and drawbacks inherent in scientific breakthroughs. Science teachers can work with students to clarify the values attendant to advances in science. As a result the learner is constantly given opportunities to gather and evaluate data, arrive at a conclusion, and then act in a responsible manner.

It is important that teachers, textbook authors, and curriculum writers deal with ethical issues as they arise in the presentation of science. Science and technology have such a profound impact on society that the study of ethics needs to be an integral part of the science curriculum.

This *Addendum* provides guidance for educators in (1) "Expectations for Learner's Achievement in Science—A Model," page 1, in which points have been identified for which ethical concerns seem especially relevant (designated *EC*); and (2) in the 11 classroom guidelines, which are listed as follows:

- The classroom climate should be one of honesty and mutual trust.
- Individual and minority viewpoints should be considered. Care should be taken that strong attitudes or differences in opinion on ethical matters are neither expressed nor interpreted as personal attacks.
- One should use divergent and open-ended questions when eliciting discussion on ethical issues. When responding to questions, teachers should seek clarification and expansion of students' views and opinions rather than evaluation and closure.
- Learners should be provided opportunities to practice ethical development on issues that are not personal or threatening to those of different races, ethnic backgrounds, and religions.
- Learners may be encouraged but should not be pressured to take public positions on ethical issues. They are often in the process of sorting their own feelings and are not yet committed to particular positions.
- No grading or evaluation should be assigned on a view or opinion, but grading may be used for facts and research used in the process of arriving at the view or opinion.
- News articles and advertisements may be useful in teaching students to distinguish between fact and opinion and in helping them learn to make appropriate inferences.
- Learners should be encouraged to listen to, make responses to, and share thoughts without being required to make immediate, unstudied judgments. Teachers should model this approach in their behavior.
- The teacher's personal opinions on an ethical issue should be identified as such. The introduction of the teacher's opinions may inhibit the students from sharing their views freely and openly and may reduce the students' motivation to seek and consider other points of view.
- Textbooks and other materials should provide information and experiences in ethical issues.
- Religious issues have no place in the science classroom and should be avoided.

See the "State Board of Education's Antidogmatism Policy" on page 106 of this *Addendum*.

The science curriculum should provide some opportunities for in-depth analysis of ethical issues, including understanding the consequences of various courses of action. Instructional time may not always permit one to explore the depths of ethical matters. In some cases it may be sufficient to call attention to and define the problems involved.

Staff Development for Better Science Teaching

For the most part the *Addendum* is concerned with the curricular expectations of science instruction. But no amount of content specification is complete without statements attesting to the pressing need for teacher training required even to maintain (much less improve) science teaching in California. This section briefly lists the rationale and suggested strategies for conducting science staff development. Staff development in science is clearly a demanding task. The intent of this section is, therefore, to describe the unique aspects and requirements of science staff development and respond to them in positive, helpful ways. Readers planning to offer science staff development programs are well-advised to discuss the following suggestions with representatives of their prospective audience (science teachers) to adapt the training to local needs.

Identifying What Is Unique About Science Staff Development

While most of what the literature on staff development has to say applies very well to science, certain qualities make science staff development unique. These special qualities present staff developers with both concerns and opportunities.

One such concern emerges from misunderstandings about what science is. Many people view science mainly as a body of accumulated knowledge. While acknowledging the special role of laboratory activity in science, these people view science teaching and learning almost exclusively as a process of passing knowledge about science from teacher to student. A more modern perspective—espoused by the 1978 *Science Framework for California Public Schools*—holds that science is both a body of knowledge and a set of processes. Acceptance of this view carries with it a commitment to *doing* science—involving learners in direct interaction with the things of their world. Because of this need for learner involvement, effective staff development in science must deal not only with knowledge about science, but also with the processes, skills, and attitudes of science as well—and this staff development must involve *doing*.

This more accurate view of science also encourages us to integrate science with other subject areas. Such science skills as observing are also basic to reading, writing, and mathematics. Skilled teachers tie science learnings to learnings in other curricular areas. By the same token skilled science staff developers also demonstrate how these relationships can best be brought out in science teaching.

Just as staff development in science engages teachers in doing science, new ways of teaching science also need to be experienced. The most effective staff development programs in science model exemplary science teaching strategies, and they frequently give teachers opportunities to practice new methodologies in low-risk settings.

The principal plays a key role in successful in-service staff development programs. Research shows that when principals take an active role in helping teachers with the technology or techniques of new instructional programs, implementation of new programs is most successful. The reverse is also true; when principals fail to get involved, success is unlikely. Principals need to take part in science staff development, both for the training they need and for the subtle guidance their involvement gives teachers—involvement that clearly says, "Science is important for our students and for society."

Planning for Success in Science Staff Development

An effective staff development program provides a wide range of opportunities for learning to occur. Donald Orlich[1] examined the research literature to identify factors known to contribute to successful staff development programs. His list includes the following ideas, shown here with specific examples for science staff development:

1. Programs that provide differentiated training experiences for different teachers (that is, individualized programs) are more likely to accomplish their objectives than are those that provide common activities for all participants.

   Suggestions

   a. Involve science teachers in the planning process. Select workshop topics and activities based on the teachers' determination of which activities will be most helpful to them.

[1]Donald Orlich, "Planning Effective In-Service Projects That Work." Paper presented at the National Science Teachers Association Annual Convention, Anaheim, Calif., March 24, 1980.

b. Build options into the program. For example, offer an array of minicourses on separate topics instead of one large workshop which everyone is expected to take.
c. Offer a variety of science workshops or activities, and have teachers select which ones to take on the basis of a self-assessment of their personal strengths and weaknesses in science.

2. Programs that place each participant in an active role (constructing and generating materials, ideas, and behaviors) are more likely to succeed than are those that place each participant in a receptive or passive role (accepting ideas and prescribed activities not of his or her making).

Suggestions

a. Avoid programs based solely on lecture presentations, unless the speaker is exceptional.
b. Break the total program into segments if it is important to provide lecture material. Mix laboratory or outdoor science activity intervals with the more passive portions of the program.
c. Emphasize hands-on activities at science staff development programs. *These programs should model better ways to teach science.*

3. Programs that emphasize demonstrations, supervised trials, and feedback are more likely to succeed than are those in which participants are expected to store up ideas and prescribed activities for a future time.

Suggestions

a. Involve the participants in actually doing what the students will be doing, both to help teachers to learn how to do it and to give them a sense of how good it feels to do science this way.
b. Use workshop assessments of progress which provide immediate and constructive feedback about the teachers' personal progress in science.
c. Give the participants ample opportunity to practice what is being learned soon after the material is presented.

4. Programs in which participants share and provide mutual assistance are more likely to accomplish their objectives than are those in which each person does separate work.

Suggestions

a. Engage the workshop participants often in group science activities, and encourage them to work with different mixes of people as the workshop progresses. (In other words, work to avoid cliques.)
b. Encourage the participants to assist each other during workshop activities. For example, you might say, "Please help that person next to you to make his or her circuit work."
c. Do not think that individualization has to mean people working alone. Individual needs may be better served if participants work with a group that has similar needs.

5. Teachers and others are more likely to benefit from staff development activities that are linked to a general effort of the school than they would if these programs are not part of a general staff development plan.

Suggestions

a. Prepare an overall staff development plan for science.
b. Plan an array of science staff development activities, in collaboration with the faculty and others, that will address all parts of your overall plan. Make sure that each person clearly understands how all the pieces fit together.
c. Make sure that all persons clearly understand their personal roles in the overall science staff development plan, as well as how the implementation of the plan will benefit them.

Responding to the Unique Challenges of Science Staff Development

	Challenges	*Possible Responses*
Elementary School Teachers	Inadequate basic science background	Provide workshops and minicourses which offer both content and hands-on activities
	Negative feelings about science	Provide workshops which emphasize the "joys" of hands-on science activities and the value of science for students and teachers. Make available a variety of children's and trade books for previewing and learning.
	Lack of confidence to teach science	Provide opportunities for teachers to teach science lessons to each other; provide teacher-to-teacher sharing of activities and approaches.
	Overreliance on textbooks and reading about science	Present workshops based on hands-on science activities; provide districtwide field trips for teachers.
	Lack of experience in managing laboratory materials and science activities	Have instructors model management procedures during workshops; discuss the best ways to manage materials; visit classes that exemplify effective management of hands-on science activities.
	Lack of science in-service staff development opportunities for elementary school teachers	Give science a high priority in planning staff development; encourage local universities to offer minicourses and workshops in elementary science.
	Disconnected science activities presented haphazardly	Present workshops which treat content, processes, and activities as themes, not as unconnected events; examine and discuss textbooks which can provide continuity and focus to a science program.
	Overemphasis on memorized information in science tests	Demonstrate the importance of concepts and processes in science; offer in-service staff development programs on writing higher order test items (for example, consider laboratory simulations requiring inference as opposed to recognizing correct multiple choice responses).
Secondary School Teachers	Teachers at maximum salary; little incentive to participate	Provide new rewards and incentives for involvement; encourage PTA or local businesses or industries to provide special programs, materials, and/or support for teachers participating in science teaching organizations, conferences, and other staff development activities.
	Overreliance on textbooks; underutilization of hands-on laboratory activity	Engage teachers in in-service staff development which models hands-on science activity; demonstrate how to use a variety of modes.
	Overreliance on lecture as the main mode of presentation	Demonstrate the benefits of alternative modes.

	Challenges	Possible Responses
Secondary School Teachers	Science background apparently good but not current	Provide speakers, workshops, and resource materials which offer motivation and fresh, updated content; encourage visitations from representatives of industry; provide current science magazines in the teachers' lounge.
	Lack of empathy for students who are less interested or less capable in science	Provide human relations workshop activities; encourage the sharing of materials which motivate and which are known to be effective with these students; have teachers visit science classes for the handicapped.
	Tendency to view science mainly as an organized body of knowledge	Provide workshop sessions which demonstrate the value and importance of science processes; offer programs by scientists who can relate content and process.
	Tendency to view basic science as out-dated or unrelated to modern technology	Provide sessions which demonstrate how basic science concepts underlie most modern applications; e.g., Newtonian mechanics has gotten us to the moon.
	Teacher isolation which inhibits the sharing of ideas with teachers from other schools, resulting in limited science curriculum content	Provide opportunities for workshops and informal sharing of ideas among the teachers from the schools within a district.
	Course content and laboratory activities too often unrelated to the student's real world	Provide staff development to reexamine the goals and priorities of science instruction; emphasize curricula which deal with genuine problems; encourage adding career information to science content.
Special Challenges of the 1980s	Underqualified science teachers	Provide basic courses and minicourses in science; collaborate with local universities; set up in-school assistance systems. Provide mentor teachers in science or other specialists to help teachers upgrade their background and skills. Enable teachers to attend science conferences. Encourage teachers to join professional science teaching organizations, such as the National Science Teachers Association (NSTA), California Science Teachers Association (CSTA), Elementary School Science Association (ESSA), and National Association of Biology Teachers (NABT). Invite parents in science professions to provide career information and/or workshops. Use televised science programs as a source of assistance. Use university interns to assist with science activities.

Challenges	Possible Responses
Science teacher burnout	Provide special workshops and programs; encourage interaction, both professionally and socially, among teachers from different schools and districts.
Rapid changes in science content and entry into the computer age	Provide ongoing training in current topics, including computer applications.
Increasing proportions of limited-English-proficient students in the schools	Provide workshops to sensitize science teachers to the problems of not being fluent in English; offer programs to encourage teachers to present hands-on (less language-dependent) science instruction.
Drastic reduction of budgets for maintaining science laboratory programs	Provide how-to workshops which use free and inexpensive materials; involve parents and community groups in acquiring and maintaining materials.
Curtailment of science supervision due to budget cutbacks	Establish science networks to share ideas; set up teacher-to-teacher support systems within schools.
Outdated textbook and classroom reference materials	Provide teacher in-service education to update the participants' knowledge of new materials; include teaching methods and data on free and inexpensive resource materials.
An increasing need to incorporate social and technological implications and applications into science courses	Provide workshops and minicourses that offer needed background and appropriate teaching and learning strategies; offer teacher/industry seminars; provide programs jointly with social science teachers.
A shortage of properly trained and credentialed science teachers, especially for physical science courses	Provide courses and minicourses, in collaboration with local universities, to retrain teachers holding other credentials.
Limited funds to offer incentives for involvement in staff development	Consider alternative awards, such as accolades, reduced teaching load, extra funds for supplies, or opportunities to attend science conventions.
Larger classes increasing the difficulty of operating hands-on science programs	Have in-service staff development programs given by teachers who have developed classroom management strategies known to work.

Special Challenges of the 1980s

Sources and Resources for Science Staff Development

The following are some helpful general references:

A Monograph on Staff Development. Sacramento: California State Department of Education, 1980.

Orlich, Donald. "Planning Effective In-Service Projects That Work." Paper presented at the 1980 annual convention of the National Science Teachers Association, March 24, 1980.

Raising Expectations: Model Graduation Requirements. Sacramento: California State Department of Education, 1983.

Science Education for the 1980s: A Planning and Assessment Handbook for Kindergarten Through Grade Twelve. Sacramento: California State Department of Education, 1982 (see especially pages 26—29).

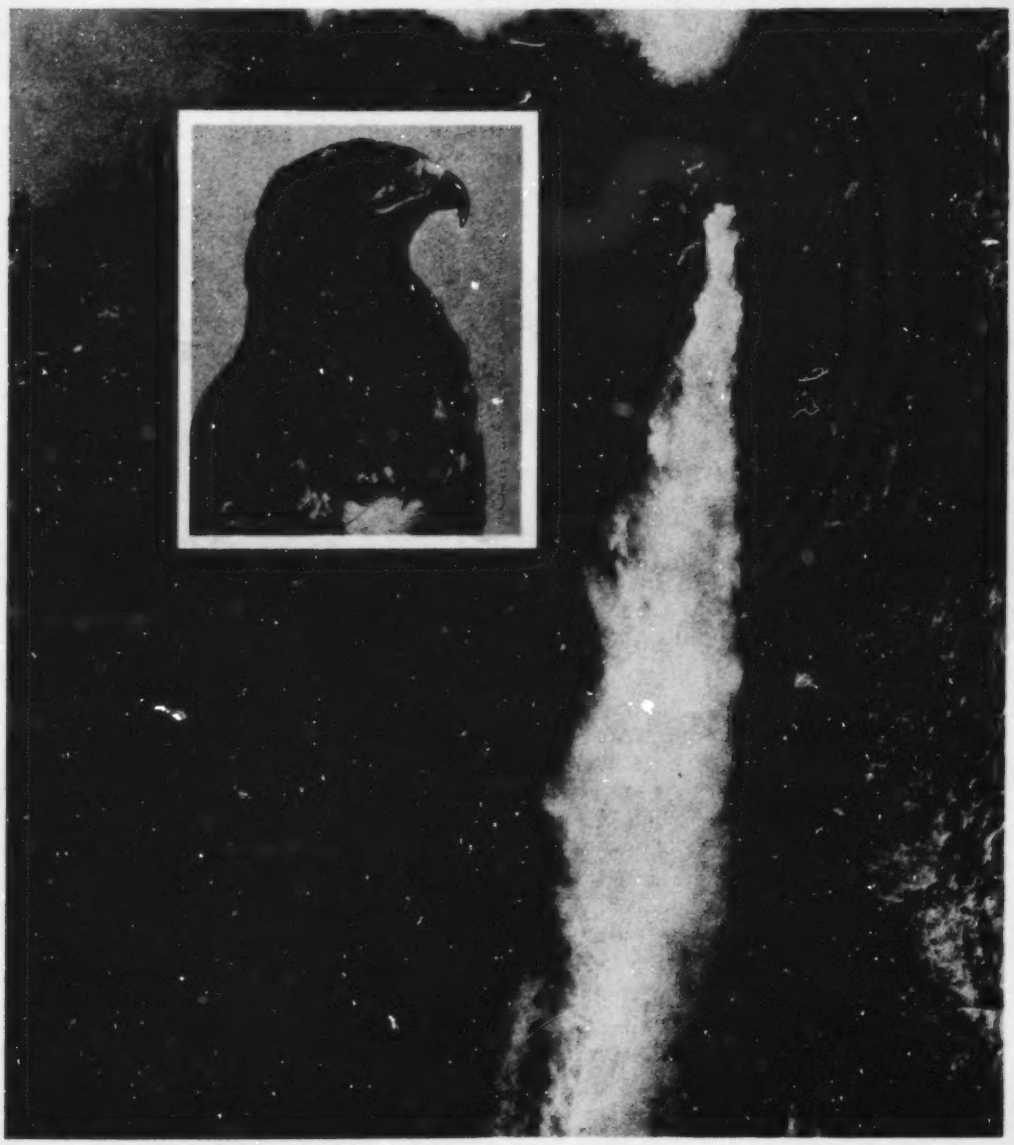
Science Framework for California Public Schools, Kindergarten and Grades One Through Twelve.

Sacramento: California State Department of Education, 1978 (see especially pages 9—10; 19—20; 51—75; and 94—98).

Staff Development/Organization Development. Alexandria, Va.: Association for Supervision and Curriculum Development, 1981.

Some suggested resource materials are listed as follows:

- For a districtwide plan for promoting and improving kindergarten through grade twelve science instruction, contact the Curriculum Coordinator, Irvine Unified School District, P.O. Box 19535, Irvine, CA 92713.
- For a sample workshop session evaluation form, contact the Science Education Office, School of Natural Sciences, California State University, Long Beach, CA 90840.
- For a sample science needs assessment instrument, contact the Office of the Contra Costa County Superintendent of Schools, 75 Santa Barbara Road, Pleasant Hill, CA 94523.
- For samples of teacher workshop science process session appraisal forms, contact the Science Education Office, School of Natural Science, California State University, Long Beach, CA 90840.
- For a copy of "Evaluation of Science Curriculum Using Objectives from the California Science Framework," contact the Science Curriculum Specialist, Mt. Diablo Unified School District, 1936 Carlotta Drive, Concord, CA 94519.



Electronic Technology in the Science Classroom

The use of technology in the classroom is not new to science education. When we discuss the space shuttle, electron microscopy, or recombinant DNA, we are explaining how technological advances help us refine our understanding of scientific concepts. When we use an apparatus, such as the triple-beam balance, pipette, or telescope, we reveal the basic tools that scientists (and students) use to conduct experiments. The use of media like instructional television, microcomputers, and even filmstrips brings technology into the classroom. So, we can think of three broad classes of technology in science education: In the first, technology is the subject of the lesson; in the second, technology provides the apparatus used to conduct experiments; and in the third, technology provides the educational medium through which the science lesson is transmitted. The first two kinds of technology in science education are woven throughout the concepts and exemplars in "Expectations for Learners' Achievement in Science—A Model." This section of the *Addendum* deals with the last of the three classes, specifically focusing on recently developed electronic technology for classroom use.

The purpose of this section of the *Addendum* is to give the reader some hints about using electronic instructional technology to enhance learning of the concepts, skills, and thinking processes. The specific themes that will be introduced and reinforced in this section are as follows:

- The principal difficulty in using electronic (or other supplemental) media in the classroom is matching the content of the software (in the generic sense) to the instructional objectives of the teacher. Therefore, teachers must preview, and base their selections on, software that helps them to attain worthwhile, relevant objectives.
- As science educators, hands-on, experiential learning is central to our teaching. It is important to exercise caution in harnessing electronic technology to perform learning activities that are more vividly rendered in hands-on experiments than with electronic simulations. The two-dimensional, stylized anatomy of the pig is not as compelling as the real-life dissection experiments. The point is that electronic media should be acquired and used only when they are more effective than learning activities already available to science teachers.
- By using teaching technology in the classroom, science educators can begin to demonstrate some procedures used by scientists. Electronic technology is especially useful in creating simulations, graphic representations of data, and other models of scientific phenomena.

These themes can be used by scientists, science teachers, and students in teaching and learning many science concepts and processes described in this *Addendum*. Teachers are the role models for science to most students. Teachers' use of technology can bring students closer to both the content *and* process of science.

Microcomputers in Science Education

The very nature of science education lends itself to an educator's trying new ideas and being an innovative and creative example for young people. The recent history of computers is a perfect example of the highest developmental level shown on the chart on page 4; i.e., applying knowledge to solve problems and inventing.

Rapid Changes in Hardware

The effective use of computers represents a great challenge to educators. The rapid changes in hardware have necessitated caution in purchasing equipment, while at the same time equipment is needed for one to acquire computer literacy. Some risk-taking has been necessary, but those who previously took the risks are leading the many who follow to make better purchasing decisions. This situation will undoubtedly continue to be true as new hardware becomes available to science teachers. One truism that has not changed in purchasing hardware is to begin by identifying software that will achieve the objectives one has in mind.

NOTE: This discussion of the application of new technology to science teaching is an extension of the *Science Framework for California Public Schools, Kindergarten and Grades One Through Twelve*, 1978, Chapter 4, pages 51—61. Familiarity with that chapter will help the reader to place this discussion in proper context. The reader should also refer to "Criteria for Evaluating Instructional Materials in Science (1984 Revision)," which is included in this *Addendum*.

There are many advances in hardware, including expanded memory and telecommunication functions, but one new development that is of special interest to scientists and science teachers is the portable computer, which can be used for applications outside the school or laboratory for data collection and analysis. Furthermore, there are devices that can be connected to data collection devices for sampling, recording, and processing of information, such as pH meters, thermometers, anemometers, and other instruments common to school laboratories.

The modem, a device for communicating with or between computers by telephone, is a useful peripheral that science teachers can use to exchange programs and curriculum material, obtain information such as accurate up-to-date reports, or tie into large data bases for quick access to scientific information.

Printers allow the rapid production of hard copy of raw laboratory data and processed data in the form of graphs and tables. Printers are useful for generating work sheets, tests, and some graphics. Computer interactions with videotape and videodisk allow access to excellent photographs and film sequences that can be used with teacher-made programs.

Large capacity memory storage devices can handle software capable of generating sophisticated graphics and larger quantities of data. Larger memory capacity allows programs to be used that can respond more quickly and in a more complex fashion to student responses with tutorial software. Hard disks, bubble memory, and nonvolatile random-access memory (RAM) chips may be available to science teachers in the future.

Software for Science Teachers

Software is available that is especially well-suited to science teaching. Simulations are useful for giving students exposure to conditions in nature or in the laboratory that are too dangerous to experience personally; e.g., volcanoes or radiation. Some experiments are simply too expensive, require equipment that is not available, or perhaps take too long, such as studies in population shift or tectonic plate movement. There is some advantage in the lack of laboratory cleanup with simulation programs. But a caution is in order. Students must not be deprived of valuable live laboratory experiences and skills merely for the sake of convenience.

Occasionally, some laboratory exercises are avoided because of the time-consuming, lengthy computations involved in data analysis. The computer can be used for graphing and computation to save student and teacher time. Likewise, the computer can analyze and display the results of class sets of data quickly, making statistical studies more meaningful to students. Of course, the knowledge of what the computer is doing and the appreciation for these time-savers should be part of the students' education.

As with most disciplines, word processors can be used in science education. They can be valuable tools for training students to write science reports. Some word processors allow computations within the text, a capability which adds a new dimension to data analysis and report writing.

Electronic spreadsheets not only can help teachers with keeping students' grades but are also useful for keeping track of departmental budgets and categories of items purchased. This capability is very helpful since orders for science materials are frequently large, consisting of many items and categories.

A related program is a data base management system that can assist teachers with inventorying science supplies, chemicals, glassware, and so forth. Scheduling programs make routine events like laboratory exercises and animal feeding schedules much easier in updating and printing new listings. Software that enables the teacher to use a card reader or an optical card reader is useful for grading tests. This same software might also be applied to a quick inventory of students' equipment in science classes. Creative application of software can enhance science teaching by organizing classroom management activities to free the science teacher to teach.

Authoring programs simplify programming for those with limited experience with a more formal language like BASIC and hold considerable promise for expanding the dimensions of computer-assisted instruction. These programs can provide science teachers with a variety of authoring capabilities, lesson assignment control, and convenient student record management. Such authoring programs can provide alternative tools used as substitutes for packaged curricula with predefined sequences, which may or may not correspond with textbooks or classroom activities.

Evaluation of science software should include showing how a piece of software supports objectives, such as those suggested in the *Science Framework* and in this 1984 *Science Framework Addendum.* A program should be scientifically sound and also fit appropriately in the curriculum. This *Addendum* will assist you to pinpoint where the software fits in the continuum. See "Criteria for Evaluating Instructional Materials in Science (1984 Revision)" in this *Addendum* for additional information about software evaluation.

Training and Resources

Training science teachers in the proper use of computers in science should include the following:

- Understanding which laboratory skills are best learned through experience and which might better be observed; i.e., simulated using computers
- Determining whether a program is appropriate to the science taught in the course or how to justify the purchase of a program by showing its

relatedness to the *Addendum* or school science curriculum
- Using word processors and other utility programs for writing laboratory reports and so forth
- Training in the use of peripherals and interfacing the computers with measuring devices; e.g., pH meters, thermometers
- Understanding the terminology of hardware and software to enhance the exchange of information and upgrading of computer skills
- Handling class data for analysis and output; i.e., training in how to manage a class with a computer for student use during laboratory exercises

Resources that can facilitate using computers in science classes include the following:

- Local user groups—to gain experience with availability of software, use of hardware, and programming fluency
- Electronic repair facilities in larger districts and county offices—to provide for regular service, repairs, and ties to peripherals
- Magazines devoted to microcomputers in education—to get articles on software, case study uses, and so forth
- Magazines devoted to disciplines, such as the *Journal of Chemical Education*—to get information (and occasional programs) for use in classroom settings
- Communication networks—to access encyclopedic references, data bases, and other source materials
- Teacher education and computer (TEC) centers—to review software programs and get exposure to new hardware

Audiovisual Recording/Playback Media

How audiovisual recording/playback media can assist the science teacher is discussed in this section. The availability and application of various kinds of hardware and software as well as the training required are examined.

Hardware and Software

Videocassette recorders (VCRs), video cameras, and playback units are now familiar in the home-use market as well as for commercial and educational use. Two VCR formats are available, Beta and Video Home Systems (VHS). Cassettes designed for one format cannot be used in the other. VCRs can be used for (1) playing commercially available prerecorded tapes (much as a projector is used to show films); (2) recording and playing back programs aired on commercial or educational television (with due regard for copyright restrictions); and (3) videotaping original material with a camera and playing it back.

A wide variety of equipment is available, including battery-operated units that can be used in the field. Multiple units can be used to copy and edit videotapes. Blank cassettes of various lengths in both formats are available and can be reused when material recorded on them is no longer needed. Commercially prerecorded cassettes include many programs that are also available as 16 mm films; and films can be copied onto videotapes.

Applications to Enhance Science Teaching

The simplest application of videocassettes is in place of 16 mm films. Like films, cassettes can enhance science teaching by bringing into the classroom phenomena that are not directly accessible to students. Earthquakes, typhoons, cells undergoing mitosis, time-lapse views of plant growth, space walks, hazardous chemical reactions, animals of Africa, and animated representations of chemical reactions are but a few examples that are already familiar to teachers and students through films. Live television and VCR add the dimension of immediacy—the ability to bring to students events as they occur or very soon after they occur. Cassettes also add more flexibility in changing speed, stopping, or reversing action, and encouraging interactive use. They also make local production of sound movies more practical and less costly than is the case using film. Satellite communication allows live televised interactions with scientists, including NASA astronauts. Local productions of videotapes offer additional ways of enhancing science education, such as:

- Bringing back to the classroom key portions of a field trip for review, or for sharing the experience with those who could not go
- Providing instruction in the use of equipment, laboratory techniques, and safety precautions, especially when not all students are doing the same laboratory experiment at the same time
- Repeating demonstrations that are especially difficult, expensive, or time-consuming to prepare
- Enhancing students' observations of phenomena through magnification, speed-up or slow-down, sound amplification, repetition, and so forth
- Making a presentation by a visiting resource person accessible to more classes or to future classes
- Confronting students with concepts rather than just terms in the process of assessing achievement
- Observing and critiquing one's own teaching

As is the case with computers, video technology should be regarded as one more means of helping students achieve important science education objectives. Use of video equipment may make some objectives more reasonably attainable, enabling science teachers to try classroom activities they could not do without this equipment. The availability of videocassettes, however, should not unduly influence the science teacher's classroom objectives, nor should tele-

vision be used to accomplish things that are better done in other ways.

Training to Operate Equipment

Very little training is needed to operate VCR playback equipment. Video cameras are not difficult to operate, though professional or artistic results come only with training and practice. Secondary students can operate the equipment. Training activities for teachers probably should be concentrated on specific ways of utilizing video to achieve science objectives and on stimulating teachers to invent new ways of exploiting this medium to benefit their students.

Other Electronic Technology

Although microcomputers and videocassette recorders have been receiving most of the attention as technological advances in the classrooms, other electronic technology is available and improving with time and should not be discounted in the modernization of science teaching. This section lists some of the media and their potential applications in the classroom.

Calculators (Handheld and Table Models)

Calculators are treated lightly in this framework because the *Mathematics Framework and the 1980 Addendum for California Public Schools, Kindergarten Through Grade Twelve* provides details on their applications in the classroom and suggestions for purchasing these devices. The cost of calculators has dropped significantly enough so that when their use is applicable in certain science courses, the school often provides class sets.

Like computers, calculators can enable users to have more experience in problem solving by reducing the time and effort involved in tedious calculations. In many cases well-planned science laboratories and activities which require the use of calculators can be a motivating tool for the slow learners as well as for the advanced students. Science teachers should give instruction in the use of any calculator exercises assigned. The technology has expanded so that new models which use voice and other sound synthesis can be used to enhance the selected units in the curriculum of the school science program, especially in physical science and upper-level physics and chemistry classes.

Preprogrammed Educational Devices

These electronic units are produced by many publishers, educational supply companies, computer companies, and toy manufacturers. Many are self-contained. Some have modular features whereby additions can be made in the form of peripherals as well as preprogrammed cartridges which plug into the unit. Many are handheld calculator size or up to microcomputer dimensions. Some have liquid crystal displays; others use fluorescent displays and light-emitting diodes or a combination of these. Some plug into a television set.

Applications include educational games which support a science concept or specific topic, problem-solving games, and/or remedial or reinforcement lessons. Lessons are imbedded in the resident memory in most units, while some provide wide choices of plug-in modules or cartridges. Some of the better units offer simulations of many kinds.

Other Electronic Devices

The creative, enterprising, up-to-date science teacher will use the myriad of electronic media to enhance the curriculum in science education. Educational toys, communication devices (e.g., wireless telephones, intercoms, toy robots, lasers, photographic equipment, burglar alarms, and so forth), and other kinds of media too numerous to name can be used in demonstrations to support a concept, showing students commercial and industrial uses and incorporating technological products in laboratory activities to enhance the students' motivation and interest.

Future of Technology in Science Classrooms

Accurate forecasts of the improvements in technology that will enhance science education in the next few years are not possible to make. Over the short term, gains in software quality and availability will do much to bring computers into the science classroom. Such advances should expand the range and impact of classroom demonstrations.

The next major refinement in video technology will apparently be the replacement of the cassette tape by the videodisk. This development is expected to provide advantages in resolution (picture quality) and in the speed of random access to portions of the recorded material. This refinement should make video technology more useful for many of the purposes outlined above and, in addition, should provide better interfacing of video recordings with computers—a truly exciting prospect.

It is possible to connect cable, computer, television, videocassette, telephone, disk drive (videodisk in the not too distant future), and printer into one integrated system. The possibilities for this arrangement in the science classroom are almost limitless. Classroom teachers will be able to dial up movies, references, satellite weather pictures, and a host of other resources. The use of this system will be the same as having access to worldwide reference resources right in the classroom.

Selected References for Technology in the Science Classroom

Science educators may find these publications useful in their classroom programs:

Billings, Karen. "Adding a Micro to Your School Picture," *Electronic Learning*, Vol. 1, No. 3 (January-February, 1982), 35—40.

Evans, Christopher. "Microcomputers in the Classroom," *Today's Education* (April-May, 1982), 11—28.

"The 1983 Educational Software Preview Guide." San Mateo: Educational Software Evaluation Consortium, Office of the San Mateo County Superintendent of Schools, 1983. This publication is copyrighted by the California State Department of Education. This guide, which was revised in January, 1984, is distributed by the Software Clearinghouse, San Mateo County Office of Education.

"A Scan of Microcomputer Journals," *The Science Teacher* (November, 1981), 43.

"Science and Engineering Education for the 1980's and Beyond," Washington, D.C.: U.S. Department of Education, 1980.

"Teaching in the Silicon Age," *The Science Teacher* (March, 1979), 33—34.

"Teaching Teachers About Computers," *Phi Delta Kappan* (April, 1980), 344—46.

"Technology and the Integrated View," *The Science Teacher* (September, 1980), 23—24.

The', Lee. "Educational Software for the Home," *Personal Computing* (June, 1982), pp. 48—52.

"What Research Says to the Science Teacher," Vol. 3. Washington, D.C.: National Science Teachers Association, 1981, 94—112.

Science educators may wish to subscribe to these newsletters:

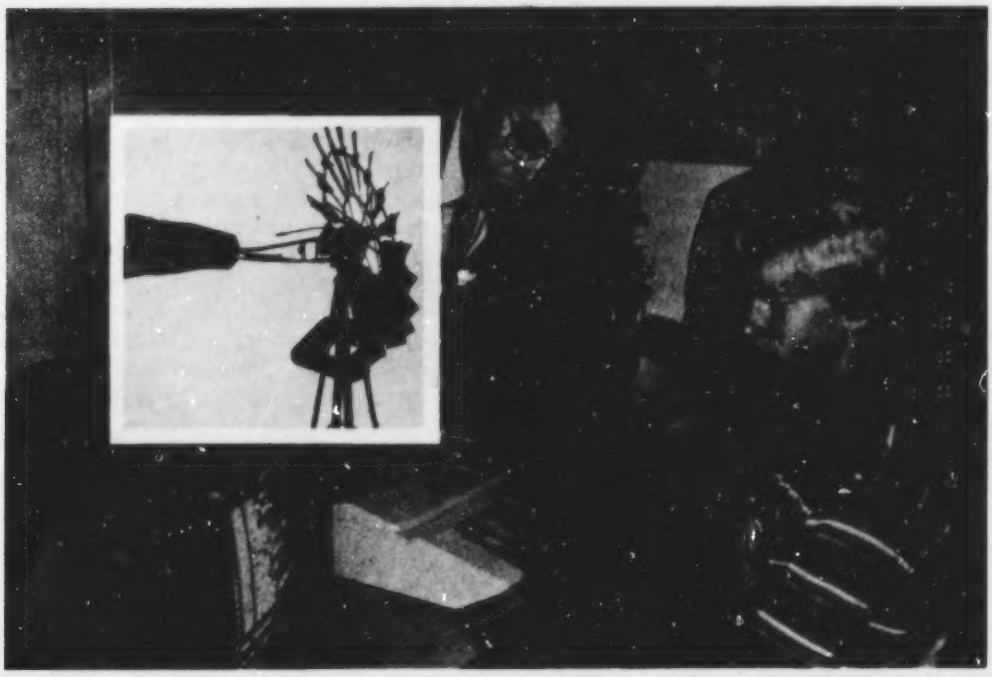
Classroom Computer News, P.O. Box 266, Cambridge, MA 02138.

Electronic Education, Suite 220, 1311 Executive Center Drive, Tallahassee, FL 32301.

These issues of computer publications may be of interest to science educators:

The Apple Journal of Courseware Review, Apple Computer, Inc., Issue 1, 1982, 8—16.

Educational Computer Magazine, Edcomp, Inc., Vol. 2, No. 5.



Criteria for Evaluating Instructional Materials in Science
(1984 Revision)

Although no single definition of science would be acceptable to everyone, in a general sense the term *science* embraces much of our objective efforts to understand nature. Applied science (technology) uses this knowledge to make the world a better place in which to live. Thus, science includes the ideas and concepts which scientists have created in order to understand nature as well as the intellectual skills and particular modes of thinking used to develop this understanding.

Goals of the Program

The goals of the science program are as follows:

1. To develop knowledge of concepts, facts, generalizations, processes, and unifying principles—the products of science—that assist in interpreting the natural environment
2. To develop those values, aspirations, and attitudes which underlie the personal involvement of the individual with the environment and society
3. To develop and apply rational thinking processes
4. To develop fundamental skills in manipulating materials and equipment; in caring for and handling living things; and in gathering, organizing, and communicating scientific information

Interrelationships in Science

Although science has been organized into such disciplines as astronomy, biology, chemistry, geology, and physics, the science program should emphasize the essential commonality of the scientific enterprise in presenting a unified picture of nature. To this end, organization along a problem-solving or skills-developing approach is preferred.

Science has not developed in isolation, nor does it exist in isolation from other activities. To place science in proper perspective, one must present this subject in the context of human endeavors. The interrelationships among science and mathematics, fine arts, social science, language arts, health education, and so forth exist and must be recognized if realistic scientific literacy is to be achieved.

Those providing science instruction must meet the different needs and interests of individual students and use appropriate teaching-learning styles, strategies, and materials.

General Criteria: The Instructional Program at All Levels

Science materials must reflect a philosophy which is consistent with that expressed in this *Science Framework Addendum for California Public Schools* as adopted by the State Board of Education.

Material in a language other than English and parallel to English curricular material shall be included when available and when in conformance with these criteria. Because these criteria are meant to be used with a complete science program, some educational materials may meet only selected parts of the criteria.

Attitudes and Values

Print and nonprint educational materials will be used by the teaching staff to:

1. Develop an understanding of the interdependence between science and society.
2. Help learners practice critical questioning of unsupported statements.
3. Help learners develop and extend their personal interests and experiences through science.
4. Develop those positive values, aspirations, and attitudes which underlie the personal involvement of the individual with the environment.
5. Promote an awareness of energy/technological/ecological relationships in the environment and of their social and economic implications.

Content and Process

Both print and nonprint educational materials will be used by the teaching staff to:

1. Provide students with a science program that will develop a knowledge of specifics: facts, conventions, sequences, and classifications.
2. Provide learners with an opportunity to develop a knowledge of concepts, generalizations, and unifying principles consistent with those outlined in the current *Science Framework* and *Addendum.*
3. Provide concepts and ideas that are appropriate to the students' levels of development,

consistent with the model contained in this *Addendum.*

4. Provide a variety of experiences in the biological, physical, earth, and space sciences. (The scope of the content may be limited for specific secondary school courses.)
5. Integrate the knowledge and skills learned in other disciplines (e.g., computer education, health education, reading, social science, spelling, and writing) with those abilities that lead to the achievement of scientific goals.
6. Demonstrate the interrelatedness of scientific information and the processes by which that information is obtained.
7. Give learners the opportunity to develop the major processes of science that are employed in scientific inquiry: observing, experimenting, verifying, predicting, organizing, inferring, analyzing, synthesizing, generalizing, and calculating.
8. Help learners develop fundamental skills in manipulating materials and equipment; in caring for and handling living things; and gathering, organizing, and communicating scientific information.
9. Emphasize standard health and safety practices.
10. Show the relationship between people and their environment, and promote awareness of and responsibility toward that environment.
11. Develop an awareness of diminishing natural resources, and emphasize the need for wiser management.
12. Describe contributions to science and technology made by women and men of various races, ages, and nationalities.
13. Identify science-related careers, and stress the importance of science to a wide variety of occupations.
14. Make consistent use of the International System of Units (SI) metric system, and convey to the learners the important contributions they can make in explaining the system to persons not familiar with these units.

Instructional Strategies

Both print and nonprint educational materials will meet the following criteria:

1. Be adaptable to a variety of teaching-learning strategies that treat all learners with respect, recognizing individual differences by adapting instruction to individual interests, needs, and learning styles.
2. Provide a structure for organizing and sequencing learning experiences with illustrative instructional models. Include group instruction planning and assessment, diagnostic/prescriptive teaching, and concept and process development.
3. Provide the learner with opportunities to select from a variety of activities that contribute to the attainment of an objective.
4. Include guidance for extending student experiences by introducing new topics and alternative paths of study, developing appropriate media, and the like.

Organization of Materials

The print and nonprint educational materials will meet the following criteria:

1. Provide an organizational perspective (print: table of contents, index, and so forth; nonprint: scope and sequence chart, and so forth).
2. Provide for an organized sequence of development that is readily apparent to both learner and teacher.
3. Be so arranged that ideas and skills reappear in varying contexts and at increasing levels of sophistication.
4. Provide questions that elicit a variety of learner responses; e.g., discussion and investigation. At the appropriate level, material should encourage higher-order questions or knowledge, comprehension, application, analysis, synthesis, and evaluation.

Assessment and Evaluation

Both print and nonprint materials will meet the following criteria:

1. Provide for a variety of evaluative techniques, teacher-student evaluation, and student self-evaluation.
2. Include provisions for frequent interim and end-of-program assessment of student progress. Some focuses for evaluation are (1) understanding of the nature of science; (2) interpretation of nature; (3) development of appropriate attitudes toward science and nature; (4) rational thinking; and (5) manipulative and communicative skills.
3. Be consistent in evaluating the stated goals and objectives of the instructional materials.

Teachers' Materials

Materials for teachers will meet the following criteria:

1. Include an overview and/or summary of each unit with goals and objectives.
2. Contain practical hints and advice such as:
   a. Itemized lists of materials and equipment
   b. Techniques for teaching science
   c. Recipes for solutions
   d. Sources of materials

e. Care and maintenance of equipment and living things
f. Primary references and additional sourcebooks
g. Suggested storage space requirements, and ordering procedures
h. Hints on how to avoid commonly encountered difficulties

3. Provide a related reference list and suggestions for extended and in-depth supplemental activities for learner and teacher.
4. Provide background information, including relevant questions, discussion and reading, expected responses, and historical information.
5. Show applications to personal decision-making attitudes, rational thinking processes, and skills and knowledge developed in science.
6. Identify common goals with other subject areas.
7. Provide suggestions for using community resources.
8. Define process skills and relate them to the specific activities.
9. Indicate standard health and safety practices.
10. Indicate the readability level of learner materials.
11. Be easily distinguishable from student materials and convenient for use; annotated student materials, for example, may be used as the teacher's edition.
12. Show consistent correlation with student materials.

Instructional Media Standards

Printed materials, such as books and laboratory manuals, will meet the following criteria:

1. Be printed in type that is clear, readable, and appropriate to the content.
2. Contain aesthetic visual arrangements, using color, illustrations, and photographs where appropriate.
3. Have paper and binding of a quality appropriate for the intended usage.

Visual nonprint presentations (e.g., film, filmstrips, videotapes, charts, and so forth) will meet the following criteria:

1. Be characterized by aesthetic appeal that contributes to the student's learning experiences.
2. Be current when necessary.
3. Fulfill the function suitable to the medium.

Materials designed for auditory presentation (records, tapes, and the like) will meet the following criteria:

1. Present voices that are clear, well-modulated, and appropriate to the role portrayed.
2. Have technical quality sufficient to reproduce the necessary sound frequencies.
3. Be appropriate in content and length for the intended audience.
4. Use standard English. (When a language other than English is presented, authentic native or near-native speakers should be provided. They should represent the voices of male and female adults and children speaking at an appropriate rate and with accurate intonation.)

Materials designed for manipulative use (e.g., laboratory equipment or games) will meet the following criteria:

1. Lead to achievement of instructional goals and objectives.
2. Conform to safety standards.
3. Be clearly identified and durable.
4. Be convenient to handle, use, and store.
5. Be replaceable and easily available from the supplier when needed; e.g., consumable materials and components of kits, systems, laboratories, games, and so forth.

Materials designed for use with microcomputer and other electronic technology (e.g., computer software) will meet the following criteria:

1. Be consistent with the curriculum goals and objectives contained in this *Addendum* (or with local curriculum standards).
2. Be evaluated for technical features according to the 1984 (revised) software evaluation form of the San Mateo Software Clearinghouse.
3. Be more effective than (or clearly supplemental to) experiential classroom activities in which students would normally participate.

For additional information on computer software and other technology, see the section in this *Addendum* entitled "Electronic Technology in the Science Classroom."

State Board of Education's Antidogmatism Policy

Court Decision in *Segraves* v. *State Board of Education*

In a judgment issued on June 12, 1981, Sacramento Superior Court Judge Irving Perluss upheld the validity of the State Board's 1978 *Science Framework* against a legal action in which it was claimed that the framework, in its discussion of the theory of evolution, violated plaintiffs' constitutional right to free exercise of their religion.

Following a week-long trial, Judge Perluss found that, in discussing evolution, Appendix A of the *Science Framework*, along with an antidogmatism policy adopted by the State Board of Education in 1972, fully accommodates plaintiffs' religious views. The only further action the court directed the State Board of Education to take is to disseminate the antidogmatism policy, which is as follows:

> That, on the subject of discussing origins of life and earth in public schools:
>
> (1) Dogmatism be changed to conditional statements where speculation is offered as explanation for origins.
> (2) Science should emphasize "how" and not "ultimate cause" for origins.

Among the plaintiffs in this lawsuit were certain staff members of the Creation Science Research Center of San Diego, whose religious belief is that God created man as man and placed him on earth.

The subject of the origin of the universe, earth, life, and humans is treated mainly in such subjects as biology, life science, anthropology, geology, and even in physics and chemistry. It is also often included in history, philosophy and other social sciences. It is in social science that the State Board of Education recommends that competing philosophical and religious theories of origins, such as "scientific creation" or "special creation," be discussed, not in the science curriculum.

School districts should be cognizant of the fact that inclusion of the theory of evolution in the school curriculum may trigger demands by religious organizations for either the elimination of evolution from the curriculum or inclusion of instruction on a particular religious viewpoint with respect to origins. In order to deal with such a situation, the following principles should be kept in mind:

(1) The theory of evolution is a theory based solely on scientific principles and may be taught in the public schools [*Epperson* v. *Arkansas*, 393 US 97 (1968)]. A scientific theory, such as the theory of evolution, is based on much more than mere speculation or belief.

(2) "The term *religion* has reference to one's views of his relations to his Creator, and to the obligations they impose of reverence for his being and character, and of obedience to his will" [*Davis* v. *Beason*, 133 US 333, 342 (1890)].

(3) There is a distinction between conducting religious instruction and teaching *about* religion. In the public schools the former is unconstitutional (*Epperson* v. *Arkansas*, supra; *Education Code* Section 51511).

(4) Neither the California nor the U.S. Constitution requires, in order to accommodate the religious views of those who disagree with the theory of evolution, that equal time be given in the curriculum to those particular religious views. In fact, it may be unconstitutional to grant equal time for that reason [*Epperson* v. *Arkansas*, supra; *Daniel* v. *Water*, 515 Fd 485, 491 (1975)].

In directing the Board to disseminate its 1972 antidogmatism policy, the court was concerned primarily with the mode of presentation and not the content of the science curriculum. Thus it reaffirmed that science, properly taught as the product of the scientific method, is by definition not dogmatic in that it is open-ended and without preset conclusions. The court's concern was therefore directed toward ensuring that science is not presented as possessing absolute answers to all questions. The court was particularly impressed with the testimony of a witness who emphasized the need for science educators to convey to the student's mind the clear understanding that science cannot exceed its own discipline and methodology.

With respect to state adoption of instructional materials, be assured that all science materials on the State Board of Education's approved list have been measured against the Board's antidogmatism policy set out above.

We commend the state's educators for the fine work they are doing in teaching science to our children and young people. We recognize that teaching is a difficult task and an awesome responsibility. We urge you to continue to take care to respect the beliefs of each student when teaching about sensitive subjects in science.

Education Code
Sections of Special Relevance to Science Educators

Education Code sections that are of special significance to science educators appear below. Included are regulations pertaining to devices designed to protect the eyes, instruction in personal health and public safety, treatment of animals, requirements for graduation, and sex education courses.

32030. Duties Regarding Eye Protective Devices

It shall be the duty of the governing board of every school district, and community college district and of every county superintendent of schools, and of every person, firm, or organization maintaining any private school, in this state, to equip schools with eye protective devices as defined in Section 32032, for the use of all students, teachers, and visitors when participating in the courses which are included in Section 32031. It shall be the duty of the superintendents, principals, teachers or instructors charged with the supervision of any class in which any such course is conducted, to require such eye protective devices to be worn by students, teachers, or instructors and visitors under the circumstances prescribed in Section 32031.

32031. Courses in Which Devices to Be Used; Substances and Activities Dangerous to Eyes

The eye protective devices shall be worn in courses including, but not limited to, vocational or industrial arts shops or laboratories, and chemistry, physics or combined chemistry-physics laboratories, at any time at which the individual is engaged in, or observing, an activity or the use of hazardous substances likely to cause injury to the eyes.

Hazardous substances likely to cause physical injury to the eyes include materials which are flammable, toxic, corrosive to living tissues, irritating, strongly sensitizing, radioactive, or which generate pressure through heat, decomposition or other means as defined in the California Hazardous Substances Labeling Act.[1]

Activity or the use of hazardous substances likely to cause injury to the eyes includes, but is not necessarily limited to, the following:

1. Working with hot molten metal.
2. Milling, sawing, turning, shaping, cutting, grinding, and stamping of any solid materials.
3. Heat treating, tempering, or kiln firing of any metal or other materials.
4. Gas or electric arc welding.
5. Repairing or servicing of any vehicles, or other machinery or equipment.
6. Working with hot liquids or solids or with chemicals which are flammable, toxic, corrosive to living tissues, irritating, strongly sensitizing, radioactive, or which generate pressure through heat, decomposition, or other means.

32032. Standards for Devices

For purposes of this article the eye protective devices utilized shall be industrial quality eye protective devices which meet the standards of the American National Standards Institute for "Practice for Occupational and Educational Eye and Face Protection" (Z87.1—1968), and subsequent standards that are adopted by the American National Standards Institute for "Practice for Occupational and Educational Eye and Face Protection."

32033. Sale of Devices at Cost to Pupils and Teachers

The eye protective devices may be sold to the pupils and teachers or instructors at a price which shall not exceed the actual cost of the eye protective devices to the school or governing board.

51202. Instruction in Personal and Public Health and Safety

The adopted course of study shall provide instruction at the appropriate elementary and secondary grade levels and subject areas in personal and public safety and accident prevention, including emergency first-aid instruction, instruction in hemorrhage control, treatment for poisoning, resuscitation techniques, and cardiopulmonary resuscitation when appropriate equipment is available; fire prevention; the protection and conservation of resources, including the necessity for the protection of our environment; and health, including venereal disease and the effects of alcohol, narcotics, drugs, and tobacco upon the human body.

[1] *Health and Safety Code* sections 28740 et seq.

51540. Treatment of Animals

In the public elementary and high schools or in public elementary and high school school-sponsored activities and classes held elsewhere than on school premises, live vertebrate animals shall not, as part of a scientific experiment or any purpose whatever:

(a) Be experimentally medicated or drugged in a manner to cause painful reactions or induce painful or lethal pathological conditions.

(b) Be injured through any other treatments, including, but not limited to, anesthetization or electric shock.

Live animals on the premises of a public elementary or high school shall be housed and cared for in a humane and safe manner.

The provisions of this section are not intended to prohibit or constrain vocational instruction in the normal practices of animal husbandry.

51225. Requirements for Graduation

No pupil shall receive a diploma of graduation from high school who has not completed the course of study prescribed by the governing board. Requirements for graduation shall include:

(a) English
(b) American history
(c) American government
(d) Mathematics
(e) Science
(f) Physical education, unless the pupil has been exempted pursuant to the provisions of this code
(g) Such other subjects as may be prescribed

The governing board, with the active involvement of parents, administrators, teachers, and students, shall, by January 1, 1979, adopt alternative means for students to complete the prescribed course of study which may include practical demonstration of skills and competencies, work experience or other outside school experience, interdisciplinary study, independent study, and credit earned at a postsecondary institution. Requirements for graduation and specified alternative modes for completing the prescribed course of study shall be made available to students, parents, and the public.

This section shall remain in effect until July 1, 1986, and as of that date is repealed unless a later enacted statute which is chaptered before July 1, 1986, deletes or extends that date.

51225.3. Requirements for Graduation Commencing with the 1986-87 School Year

(a) Commencing with the 1986-87 school year, no pupil shall receive a diploma of graduation from high school who, while in grades 9 through 12, has not completed:

(1) At least the following numbers of courses in the subjects specified, each course having a duration of one year.

(A) Three courses in English.
(B) Two courses in mathematics.
(C) Two courses in science, including biological and physical sciences.
(D) Three courses in social studies, including United States history and geography; world history, culture, and geography; and American government, civics, and economics.
(E) One course in fine arts or foreign language.
(F) Two courses in physical education unless the pupil has been exempted pursuant to the provisions of this code.

(2) Such other coursework as the governing board of the school district may by rule specify.

(b) The governing board, with the active involvement of parents, adminstrators, teachers, and pupils, shall adopt alternative means for students to complete the prescribed course of study which may include practical demonstration of skills and competencies, supervised work experience or other outside school experience, interdisciplinary study, independent study, and credit earned at a postsecondary institution. Requirements for graduation and specified alternative modes for completing the prescribed course of study shall be made available to pupils, parents, and the public.

51550. Sex Education Courses[1]

No governing board of a public elementary or secondary school may require pupils to attend any class in which human reproductive organs and their functions and processes are described, illustrated or discussed, whether such class be part of a course designated "sex education" or "family life education" or by some similar term, or part of any other course which pupils are required to attend.

If classes are offered in public elementary and secondary schools in which human reproductive organs and their functions and processes are described, illustrated or discussed, the parent or guardian of each pupil enrolled in such class shall first be notified in writing of the class. Sending the required notice through the regular United States mail, or any other method which such local school district commonly uses to communicate individually in writing to all parents, meets the notification requirements of this paragraph.

Opportunity shall be provided to each parent or guardian to request in writing that his child not attend the class. Such requests shall be valid for the school year in which they are submitted but may be with-

[1]References to related sections from the *Education Code* appear in the *Health Instruction Framework for California Public Schools*. Sacramento: California State Department of Education, 1978, p. 68.

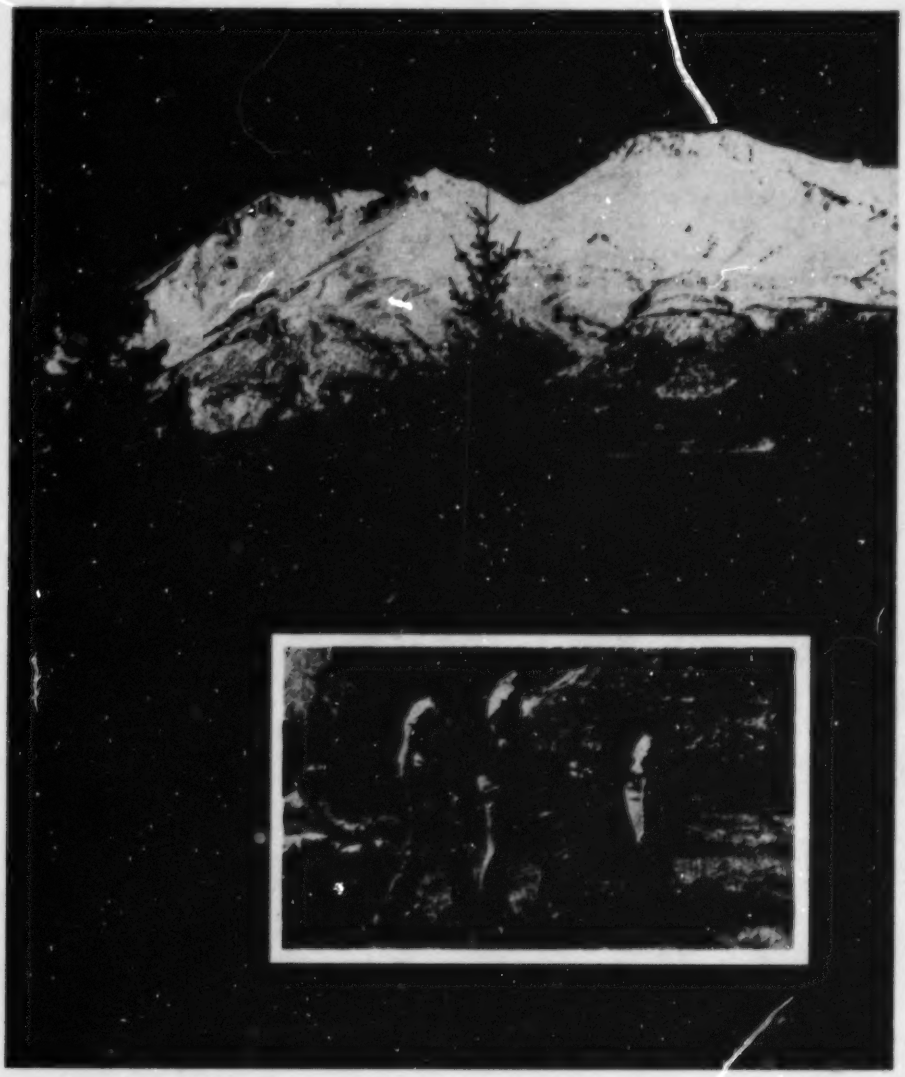
drawn by the parent or guardian at any time. No child may attend a class if a request that he not attend the class has been received by the school.

Any written or audiovisual material to be used in a class in which human reproductive organs and their functions and processes are described, illustrated, or discussed shall be available for inspection by the parent or guardian at reasonable times and places prior to the holding of a course which includes such classes. The parent or guardian shall be notified in writing of his opportunity to inspect and review such materials.

This section shall not apply to description or illustration of human reproductive organs which may appear in a textbook, adopted pursuant to law, on physiology, biology, zoology, general science, personal hygiene, or health.

Nothing in this section shall be construed as encouraging the description, illustration, or discussion of human reproductive organs and their functions and processes in the public elementary and secondary schools.

The certification document of any person charged with the responsibility of making any instructional material available for inspection under this section or who is charged with the responsibility of notifying a parent or guardian of any class conducted within the purview of this section, and who knowingly and willfully fails to make such instructional material available for inspection or to notify such parent or guardian, may be revoked or suspended because of such act. The certification document of any person who knowingly and willfully requires a pupil to attend a class within the purview of this section when a request that the pupil not attend has been received from the parent or guardian may be revoked or suspended because of such act.



Publications Available from the Department of Education

This publication is one of approximately 500 that are available from the California State Department of Education. Some of the more recent publications or those most widely used are the following:

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California State Department of Education
P.O. Box 271
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A complete list of publications available from the Department, including apprenticeship instructional materials, may be obtained by writing to the address listed above.

A list of approximately 100 diskettes and accompanying manuals, available to member districts of the California Computing Consortium, may also be obtained by writing to the same address.

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